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ABSTRACT

This report describes and discusses the results of a 5-year program evaluating the effectiveness of computer-assisted instruction (CAI) for compensatory education of elementary school students. The report comprises seven parts: (1) an overview of the final report, in which project background, methodology, findings, and implications are summarized; (2) a descriptive study of CAI in compensatory education, in which the setting for the project, the acquisition and operation of the CAI systems, and various perspectives on CAI are discussed; (3) a description of the CAI curricula employed during the project, including accounts of the mathematics, reading, and language arts curricula, student time on computers, and student progress in CAI curricula; (4) an analysis of the effectiveness of CAI, in which research design and methodology, 1-year experimental studies, longitudinal studies, and treatment effects are discussed; (5) a descriptive review of longitudinal patterns of student attitudes toward the CAI curriculum; (6) an assessment of CAI as an instructional medium in the Los Angeles County Unified School District setting; and (7) an evaluation of the costs of CAI and a meta-cost-effectiveness analysis of educational intervention. (JL)

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Project Report Number 19

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

THE FINAL REPORT

April 1982

Marjorie Ragosta
Paul W. Holland
and
Dean T. Jamison

The Program on Teaching and Learning,
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Educational Testing Service, Princeton, New Jersey

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The project has produced some 20 project reports over its years, including yearly reports on procedures and implementation for that year and on the year's data analysis. However, most of these are superceded by or included in the seven-part Final Report (bound as a single 500-page document). Those most relevant include:

#2. Project Handbook for CAI Coordinators, December 1976 (by Marjorie Ragosta and others).

#11. Assessing Basic Arithmetic Skills Across Curricula, December 1978 (by Donald Alderman and others). Also in The Journal of Children's Mathematical Behavior, 1979, 2(2).

#14. Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. An Evaluation of the Costs of Computer-Assisted Instruction, (by Henry M. Levin and Louis Woo), October 1979. Reprinted as Part 7A of Final Report (Project Report #19), and also in Economics of Education Review, 1(1) Winter (1981), 1-25.

#19. Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report, April 1982 (by Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison).
   Part 1. Overview (36 pp.)
   Part 2. Descriptive Study (122 pp.)
   Part 3. The CAI Curriculums (36 pp.)
   Part 4. The Effectiveness of CAI (187 pp; for technical reading)
   Part 5. Longitudinal Patterns of Student Attitudes in a Computer-Assisted Instruction Curriculum (15 pp.) (by Philip Griswold)
   Part 6. Assessment of the Effectiveness of Computer-Assisted Instruction in the ETS-Los Angeles Study and a Comparison of CAI with Several Intervention Strategies (65 pp; for technical reading) (by Gene V. Glass)
   Part 7A. An Evaluation of the Costs of Computer-Assisted Instruction (34 pp.) (by Henry M Levin and Louis Woo)
   Part 7B. Towards a Meta Cost-Effectiveness Analysis of Educational Interventions (29 pp.) (by Henry M. Levin and William Seidman)

#20. Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. The Executive Summary and Policy Implications, June 1982 (by Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison).

The project also served as the basis for a symposium entitled "Computer-Assisted Instruction: A Longitudinal Study" at the Annual Meetings of the American Educational Research Association, April 1980, chaired by Robert A Davis (U. Illinois at Urbana. Presenters included Dean Jamison (World Bank), Marjorie Ragosta (ETS), Warren Juhnke (LAUSD Dep. Supt.), Roberta Woodson (LAUSD Computer Lab Coordinator), and Paul Holland (ETS), with a critique by Henry M. Levin (Stanford U.).

The project director also has a presentation scheduled at the 1983 (Montreal) Annual Meetings of AERA and has been interviewed for several projected articles in the mass media (N.Y. Times, Electronic Learning, ETS Developments, and the premiere issue of the new journal Machine Mediated Learning).

Project Reports

1.	Phase I Final Report: Research Design (By Paul W. Holland, Dean T. Jamison, and Marjorie Ragosta, with Edmund G. Gordon, Rob Patrick, Frank Toggenberger, and Gita Wilder)	October 1976
2.	Project Handbook for CAI Coordinators (By Marjorie Ragosta and Vernona Blair, Kathleen Keene, Marjorie Lord, Barbara Mosby, Mary O'Neal, Ann Vasilopoulos, Roberta Woodson, with Paul W. Holland, Audrey McDaniel, and Rob Patrick)	December 1976
3.	Project Initiation (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	March 1977
4.	Instruments: Year 1 (By Marjorie Ragosta)	September 1977
5.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Year One: Final Report. (By Marjorie Ragosta, Dean T. Jamison, and Paul W. Holland) (Revision of September, 1977 Report)	March 1978
6.	Project Summary	March 1978
7.	Analysis of the Data for the First Year of the ETS/LAUSD CAI PROJECT (By Paul W. Holland, Dean T. Jamison, and Marjorie Ragosta)	March 1978
9.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report: Fiscal Year 1978 (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	September 1978
10.	Preliminary Data Analysis Report, School Year 1977-78 (By Paul W. Holland, Dean T. Jamison, and Marjorie Ragosta)	September 1978
11.	Assessing Basic Arithmetic Skills Across Curricula. (By Donald Alderman, Spencer Swinton, and James S. Braswell)	December 1978

Project Reports - continued

12.	Data Analysis: Fiscal Year 1978 (By Paul W. Holland, Dean T. Jamison, and Marjorie Ragosta)	January 1979
13.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report 1978/79 School Year. Preliminary Data Analysis. (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	October 1979
14.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. An Evaluation of the Costs of Computer-Assisted Instruction (By Henry M. Levin and Louis Woo)	October 1979
15.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. 1978/79 School Year: Final Report. (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	April 1980
16.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Outline of the Final Report and Data Analysis Plan. (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	May 1980
17.	Thoughts on a CAI Program: CAI Coordinators Debriefing Conference. (By Marjorie Ragosta, with Mary King, Marjorie Lord, Judy Newman, Ann Vasilopoulos, Rayma Wells, and Roberta Woodson)	June 1980
18.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Implementation Report 1979/80 School Year. (By Marjorie Ragosta)	September 1980
19.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report. (By Marjorie Ragosta, Paul W. Holland, and Dean T. Jamison)	March 1982
20.	Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. The Executive Summary and Policy Implications. (By Marjorie Ragosta)	March 1982

Acknowledgements

In any project, the help of many people is required. But when that help is given enthusiastically and unstintingly, special thanks are due. That was the case in this project.

We were especially fortunate to be working with the administrators, principals, teachers, staff and students in our schools in the Los Angeles Unified School District. We could not have had a better group with which to carry out the project. Worthy of special mention is Dr. Warren Juhnke, the LAUSD Project Director, who assisted and promoted the project wholeheartedly while carrying out his responsibilities as Deputy Administrator of Area D (now Area 4). The day-to-day success of the CAI program was largely the responsibility of the CAI coordinators who, with the assistance of their T.A.'s, managed the CAI labs. They were a friendly, dedicated and responsible group and our grateful thanks go out to each of them: Marjorie Lord, Ann Vasilopoulos, Rayma Wells, Roberta Woodson, Mary King, Barbara Mosby, and Judy Newman. To all of the teachers and principals who were so cooperative and to all of those well-tested students who participated in the project, we send our appreciation. Thanks to all of you in Los Angeles who helped to make the project a success.

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Last, but not least, we mention our colleagues at ETS. To the classroom observers--Joyce Gant, William Nemceff, Puff Rice and Gina Wilson--we send our appreciation for a job well done. To Yu-Chung (Jeff) Wang who coordinated the data analysis activities and to the data analysts--Rob Patrick, Dave Saxe, Dorothy Proskin, Jim Ferris, Bruce Kaplan, Dave Freund, Al Griffin and others--we extend our thanks for dealing with a data base as complicated as this one. Thanks to Gina Wilson, Gene Horkay and his staff for assistance with the financial aspects of the project. To Garlie Forehand and Puff Rice we owe a debt of gratitude for reading, editing and improving the Final Report. To many others who helped the project in various ways--Don Alderman, Cathy Fairall, Henrietta Gallagher, Frieda Hardy, Charity Hicks, Christine Sansone, Spencer Swinton, Gita Wilder and others--many thanks. Our special appreciation goes to Teri Mondeaux who produced our many project reports and contended with hundreds of day-to-day details which needed attention. And, finally, we wish to thank Irene Smith for her work in completing the final report.

To all, our heartfelt thanks!

Contents of the Final Report

This volume is the final report of a five-year study of computer-assisted instruction funded by the National Institute of Education and conducted by Educational Testing Service and the Los Angeles Unified School District. In addition to the Executive Summary, the final report is composed of seven parts, the contents of which are described below:

Part 1		Overview of the Final Report
Part 2		A Descriptive Study
Part 3		The CAI Curriculums
Part 4		The Effectiveness of CAI
Part 5		Longitudinal Patterns of Student Attitudes in a Computer-Assisted Instruction Curriculum
Part 6		Assessment of the Effectiveness of Computer-Assisted Instruction in the ETS-Los Angeles Study and a Comparison of CAI with Several Intervention Strategies
Part 7	A.	An Evaluation of the Costs of Computer-Assisted Instruction
	B.	Towards a Meta Cost-Effectiveness Analysis of Educational Interventions

Executive Summary

School systems concerned with compensatory education have for years sought techniques with three essential characteristics: effectiveness, replicability, and costs within typical per-student Title I allocations. Funded by the National Institute of Education, Educational Testing Service (ETS) in conjunction with the Los Angeles Unified School District (LAUSD) spent more than five years evaluating computer-assisted instruction (CAI) for compensatory education. The results were heartening.

Four elementary schools were equipped with CAI labs using terminals and printers operated by a minicomputer. Computer-assisted instruction was provided by drill-and-practice curriculums in mathematics, reading and language arts leased from Computer Curriculum Corporation in Palo Alto, California. Students were randomly assigned to the CAI curriculums as part of the project's research design.

The curriculums proved to be effective in raising students scores not only on tests derived from the CAI curriculums (CSTs) but on standardized tests as well. Fourth to sixth-grade students who received 10 minutes per day of reading CAI performed at the 60th-65th percentile of students without reading CAI at the end of only one year. Similarly, students receiving 10 minutes of language-arts CAI performed at the 54th-76th percentile of students without language arts. In most cases those performance levels were maintained over three years with continued use of CAI. The students in grades 1-6, who received up to 20 minutes per day of mathematics drill-and-practice on the computer, fared even better. On standardized tests of mathematics computation, CAI students performed at the 64th percentile of their control groups at the end of only one year, at the 71st percentile by the end of two years, and at the 76th percentile at the end of three years. On the CSTs they increased from the 79th percentile in year 1, to the 82nd percentile in year 2, to the 89th percentile by the end of year 3. The effectiveness of all three CAI curriculums was demonstrated.

Replicability was demonstrated by fairly consistent results over the four years of the study. Although school environment and personnel affect the CAI program, the drill-and-practice curriculums themselves interacted consistently with students across schools and across years. The major inconsistency was the suitability of the reading and language arts curriculums for all elementary school students. Some students in grades 4-6 were unable to use the curriculums because they could not read at a third grade level and a few were so fluent in English that they completed the courses before the end of grade 6. The mathematics curriculum, on the other hand, was used by students from kindergarten to sixth grade and only two girls completed the program after having 20 minutes per day of instruction from grade 2 - grade 5.

The per-pupil cost of the CAI program was within Title I allocations for 1977-78. It cost about $100,000 a year to provide a classroom, personnel and equipment for operating a CAI laboratory. Slightly more than one-third of the cost was for facilities and equipment, an equivalent amount was spent on personnel and the remainder was spent on curriculum rental, maintenance contracts and supplies. One 10 minute session of CAI daily over the school year was estimated to cost about $130 using a CCC-17 minicomputer to operate 32 terminals. Up to three 10 minute sessions of drill-and-practice could be provided daily for each disadvantaged child at the 1977-78 level of Title I expenditure.

The cost-effectiveness of CAI vs. other intervention strategies was unable to be estimated within the constraints of the project. The effectiveness of CAI was compared to the effectiveness of other interventions: reduction in class size, tutoring, instructional television and electronic calculators. Although the effectiveness of the mathematics CAI curriculum appeared to approximate the effectiveness of tutoring, the costs of interventions other than CAI were not immediately available for comparison.

In addition to effectiveness, replicability and cost, educational administrators may be concerned about the acceptance of computer-assisted instruction by school personnel. Although initial acceptance by teachers was less than wholehearted, by the end of the study most teachers were convinced of the value of CAI and supported it fully. The CAI coordinators who managed the CAI labs were most enthusiastic about the help that CAI gave in improving students' skills. Principals enjoyed bringing visitors to the CAI labs and parents filled the labs at every opportunity. Students enjoyed the CAI program as well, although they sometimes complained of the restrictions caused by the research design.

> CAI is real boring, but I guess it would
> be better if I had reading or language,
> but I'm stuck with math.

Only 10-13 percent of students had any negative comment, however. Most were strongly supportive:

> Computers is an exciting event, everybody is working and trying hard to get one hundred percent. It feels like we're a great big family, just doing our jobs, so I like computers...
>
> I think the CAI program is fantastic. I think the program should be spread through out every school system in America.

The overall acceptance of the CAI program in Los Angeles was excellent. In 1982, two years after the government support for the project ended, the Los Angeles Unified School District is supporting the continued operation of the CAI labs.

PART 1*

COMPUTER-ASSISTED INSTRUCTION AND
COMPENSATORY EDUCATION:
THE ETS/LAUSD STUDY

OVERVIEW
OF THE
FINAL REPORT

April 1982

Marjorie Ragosta

The Program on Teaching and Learning,
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FINAL REPORT TO THE U. S. NATIONAL INSTITUTE OF EDUCATION, APRIL 1982.

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INTRODUCTION

With the passage of the Elementary and Secondary Education Act of 1965, the Federal Government through Title I assumed a major role in solving the nation's problem of providing compensatory education for disadvantaged students. The search began for a technique of compensatory education that combined three essential characteristics: effectiveness in substantially improving the performance in basic skills of the compensatory population, replicability beyond the original site, and costs within typical per-student Title I allocations.

A decade of developmental work, mostly centered at Stanford University's Institute for Mathematical Studies, resulted in a set of three computer-assisted instruction (CAI) curriculums for elementary-school compensatory education. Early studies indicated that their costs fell well within per-pupil Title I allocations[1] and that use of the mathematics curriculum over a period of one year improved student performance in mathematics.[2] Since the curriculums were available for use with minicomputers or large mainframe computers, replicability of the compensatory intervention could be assured.

If these CAI curriculums could be conclusively shown, over a period of several years, to provide a pedagogically effective intervention, then state and local educational authorities could be assured of having at least one demonstrably satisfactory compensatory intervention at their disposal. If, on the other hand, further research overturned the initially positive findings, unnecessary outlays on this form of CAI could be avoided.

A joint venture funded by the National Institute of Education (NIE) was begun in 1976 by Educational Testing Service (ETS) and the Los Angeles Unified School District (LAUSD) to examine these issues. The purpose of the ETS/LAUSD computer-assisted instruction study was to answer definitely the question of whether these available CAI curriculums were effective. In particular, the study which extended over more than five years, was designed to answer the following questions:

(1) Are these CAI curriculums effective with use during one school year?

(2) Can the CAI curriculums continue to assist students over two or three years of their elementary-school experience?

Additional questions for which answers were sought were how well students and school personnel accepted the CAI program, and through what possible mechanisms CAI achieved its effectiveness. In order to strengthen the findings external consultants were asked to do a cost-analysis of the CAI program as used in the study and to evaluate the CAI effectiveness data from the study and compare its effectiveness with other intervention strategies.

In the executive summary of the results presented in the final report, the following topics will be covered:

- Background and Research Design
- The Effectiveness of the CAI Curriculums
- Costs and Cost-Effectiveness
- Perspectives on CAI from School Personnel
- Implications for Schools

Background and Research Design

Four elementary schools in Area D (now Area 4) of the LAUSD were selected to receive CAI labs, and two additional elementary schools were selected to provide comparison groups of students. Work on the construction of the CAI labs began in September, 1976, and the labs were completed in January, 1977. For the remainder of that school year, and for the next 3 years, at least half of the students in each of the CAI schools received regular drill-and-practice instruction.

The study sought the most widely applicable drill-and-practice computer programs in basic skills available for elementary schools in 1976. The following drill-and-practice CAI curriculums were leased from Computer Curriculum Corporation in Palo Alto, California:[3]

Mathematics Strands: Grades 1-6. (Containing number concepts, horizontal addition, horizontal subtraction, vertical subtraction, equations, measurement, horizontal multiplication, laws of arithmetic, vertical multiplication, division, fractions, decimals, and negative numbers.)

Reading: Grades 3-6. (Containing word attack, vocabulary, literal comprehension and work-study skills.)

Language Arts: Grades 3-6. (Containing principal parts; verb usage; subject-verb agreement; pronoun usage; contractions, possessives and negatives; modifiers and sentence structure.)

Reading-for Comprehension used in Grade 4, year 4 only. (Containing the 5 strands in the older reading curriculum plus a paragraph strand.)

Each of the curriculums was composed of multiple topics or strands available across several grade levels. The computer program adapted its delivery of each strand of the CAI curriculum to the performance level of each student and moved the student along at the individual's own rate of progress.

Multiple-choice or open-ended questions were presented one at a time on the terminal screen and students typed in their responses. At the end of each 10-minute session, the students' scores were computed including: the number of items attempted, the number of correct items, and the percent of items correct.

The Research Design[4]

The research design determined not only which students would--or would not--receive CAI but also determined which CAI curriculum--or combination of curriculums--the student would be exposed to. In the CAI schools in year 1 all students in grades 2, 4 and 6 received CAI; students in grades 1, 3 and 5 served as cohort controls with no CAI. In subsequent years alternate waves of students continued to receive--or not receive--CAI. The result was 12 one-year studies of CAI (three each year for four years) which combined to create three longitudinal studies of CAI: grades 1-3, grades 2-5 and grades 4-6.

A more important control group was provided by the random assignment of students to their CAI curriculums (See Table 1). In grade 4, year 1, for example, students were randomly assigned within classrooms either to two sessions of mathematics CAI (MM) or one session of reading and one of language (RL) or one session of mathematics and one session which alternated between reading and language (MRL). The RL group served as a control for the MM and MRL groups when the effectiveness of the mathematics CAI curriculum was being assessed and, conversely, the MM group served as a control in studies of the reading and language CAI curriculums. The CAI assignments for the longitudinal studies are described below.

Table 1

CAI Treatment Over 4 Years

(NOTE: M = Mathematics CAI, R = Reading CAI, L = Language CAI, C = Reading for Comprehension CAI)

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Year 1 1976/1977		**Random within Class** M: 7 minutes daily vs. MM: 14 minutes daily		**Random within Class** MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily		**Random within Class** MM: 20 minutes daily vs. RR: 20 minutes daily vs. LL: 20 minutes daily vs. RL: 20 minutes daily
Year 2 1977/1978	**Random by Class** M: 7 minutes daily vs. No CAI	COHORT CONTROLS	**Random within Class** ML: 20 minutes daily vs. MM: 20 minutes daily	COHORT CONTROLS	**Random within Class** MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily	
Year 3 1978/1979		**Random by Class** M: 10 minutes daily vs. No CAI		**Random within Class** RL: 20 minutes vs. MM: 20 minutes **Random by Class** T. & Th. vs. M/W/F	COHORT CONTROLS	**Random within Class** MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily
Year 4 1979/1980			**Random within Class** M: 10 minutes daily vs. L: 10 minutes daily	**Random within Class** M: 10 minutes daily vs. R: 10 minutes daily vs. L: 10 minutes daily vs. C: 10 minutes daily	**Random within Class** RL: 20 minutes daily vs. MM: 20 minutes daily	

Grades 1-3	Only the mathematics CAI curriculum was available in grades 1 and 2. Classrooms were randomly assigned to the CAI labs and students had 10 minutes of drill and practice in mathematics daily. In grade 3, students were randomly assigned within classrooms to either mathematics or language CAI for 10 minutes daily. In this longitudinal study students were randomly assigned to CAI independently each year. Assignments were not automatically carried over from one year to the next.
Grades 2-5	In grade 2 students received one or two seven-minute sessions of mathematics CAI. In grade 3 they received two 10-minute sessions of CAI daily, either two sessions of mathematics (MM) or one session of mathematics and one of language (ML). Those students who received ML in grade 3 received reading and language (RL) during grades 4 and 5, while MM students continued to receive double sessions of mathematics. Once students were assigned to the MM curriculum in grade 3, they continued their assignment through grade 5 while ML students in grade 3 converted to an RL assignment for grades 4 and 5.
Grades 4-6	All three CAI curriculums were available to this group from their initiation into CAI. One-third of the group received two sessions of mathematics CAI daily (MM), one-third received one session of reading and one of language daily (RL), and one-third received one session of mathematics and one session of reading alternating with language (MR/L). Students continued their fourth-grade assignments in grades 5 and 6, while new students continued to be randomly assigned.

The two one-year studies not covered by a description of the longitudinal studies were grade 6 in year 1 and grade 4 in year 4. The latter study was designed to test the independent effectiveness of the reading and language curriculums and a newer reading-for-comprehension curriculum.

Statistical Methodology[5]

Students were tested each fall and spring with both standardized tests--the Iowa Tests of Basic Skills (ITBS) and the Comprehensive Tests of Basic Skills (CTBS)--and curriculum specific tests (CSTs). The CSTs for each grade level were composed of 100-120 questions taken directly from each of the CAI curriculums. The roles of the standardized tests and curriculum-specific tests were different. The CSTs were designed specifically to measure whether or not each of the CAI curriculums was successful in improving students' performance on the curricular material. Although the CTBS items were not directly related to the CAI curriculums, the CTBS was used as a standardized measure of general performance in mathematics, reading, and language arts. Treatment effects on the CSTs estimate the upper bound of CAI effectiveness while the CTBS effects estimate the lower bound.

The summary statistical measure of the effectiveness of the various CAI curriculums was an estimated treatment effect derived from a regression analysis in which the effect was adjusted for pretest scores, sex, ethnicity and classroom differences. The treatment effect was standardized by defining it as that proportion of the residual standard deviation accounted for by the greater (+) or lesser (-) numbers of correct responses given by CAI students. The standardized treatment effect was used to average the effectiveness of CAI across varying numbers of studies. Interpretation of the standardized treatment effect derives from widely known norms for the rate of achievement growth per month of typical schooling. At most elementary school grades, for most measures of educational achievement, the difference between the average pupil at the beginning and end of the same grade is about 1.00 standard deviation units. One month spent in school accounts on the average for a growth of 0.10 standard deviation units. In addition, the treatment effect in standard deviation units can be used to determine (by area under the normal curve) the percentile level of performance of one group over another. Thus, a 0.10 standardized treatment corresponds to the 54th percentile of the control group; a standardized treatment effect of 0.30 is equivalent to the 62nd percentile.

The Effectiveness of the CAI Curriculums[6]

The three CAI curriculums--Mathematics Strands, Reading, and Language Arts--will be discussed separately.

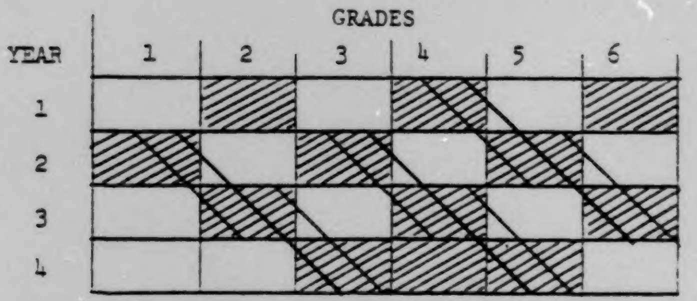
Mathematics Strands

The mathematics strands curriculum had the length and breadth to handle all of the students in the CAI study over its 4-year duration. All students were able to access the mathematics curriculum. Even kindergarten students, who were not in the study, visited the CAI lab in one of the schools on a regular basis. Only two students completed the mathematics CAI curriculum; both were girls who had been in the program for 4 years, receiving 20 minutes of mathematics CAI daily.

Students at all grade levels benefitted from the CAI mathematics curriculum and there were indications that long-term students showed continuing gains over time. There were 12 one-year studies of the CAI mathematics curriculum, six two-year studies, and three three-year studies. An overview of the mathematics studies is presented in Table 2, with single-year studies indicated by the striped rectangles and multi-year studies indicated by the longer diagonal lines.

Table 2

The Mathematics Studies



Statistical results. There were four measures of CAI treatment effects in mathematics: the curriculum-specific test (CST), and three subtests of the CTBS--computation, concepts and applications. For each of the measures, treatment effects for mathematics CAI were defined in terms of standard deviations above or below the adjusted mean performance of students without mathematics CAI and were averaged for one-year, two-year, and three-year studies. The results are presented in Table 3.

Table 3

Summary of the 1-Year, 2-Year, and 3-Year Studies of Mathematics CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Math CST	12	6	3	.80**	.91**	1.23**	79	82	89
CTBS Computation	9	6	2	.36**	.56**	.72**	64	71	76
CTBS Concepts	7	5	2	-.02	.12	.09	49	55	54
CTBS Applications	7	5	2	.03	.12	.26	51	55	60
CTBS Concepts & Applications[1]	2	1	0	.34**	.50	-	63	69	-

** $p < .01$.

[1] In grades 1 and 2 Concepts and Applications is a single subtest.

For the CSTs, the average treatment effect for the 12 one-year studies was .80 of a standard deviation, indicating that students receiving mathematics CAI were, on the average, four-fifths of a standard deviation higher than other students in mathematics performance on the CST at the end of one year. For the 6 two-year studies, the average treatment effect was .91 and for the 3 three-year studies was 1.23. Over time, the mathematics CAI groups increased their mean distance from the non-mathematics CAI groups on the tests of the CAI curriculum. The CST results indicate that the mathematics strands curriculum was effective in giving students drill-and-practice in mathematics computation. Students in the mathematics CAI curriculum outperformed other students on the test of their CAI curriculum. Results for the standardized test are less striking but similar.

On the standardized test--the CTBS--the 12 one-year studies showed an average treatment effect of .31 standard deviation on mathematics computation. That figure rose to an average of .36 when first year studies were omitted (because testing occurred only two months after the CAI labs opened). For the 6 two-year studies the average treatment effect was .56, and for the 2 three-year studies was .72. Over time, the mathematics CAI groups increased their distance from the non-mathematics CAI groups on the CTBS computation subtest.

On the CTBS concepts and applications subtests, the results were less clear. In grades 1 and 2 concepts and application problems comprise one subtest. CAI treatment effects in the 3 one-year studies averaged one-third of a standard deviation and were statistically significant. The one two-year study reported a treatment effect of .50. Of the 9 one-year studies at grade 3 or higher, the mean CAI treatment effects on mathematics concepts and applications were close to zero. When the 5 two-year studies were averaged, the mean effects for concepts and applications were .12 and .12. Mean treatment effects for concepts and applications in the 2 three-year studies were .09 and .26.

Discussion. The Mathematics Strands curriculum was designed to provide drill-and-practice CAI in computation. The CST and the CTBS computation subtest provided the best indicators of the curriculum's effectiveness in helping students improve computational skills. Results from both measures indicated significant treatment effects due to use of Mathematics Strands curriculum for only one year and increasing treatment effects with its use over two and three years. The CST and the CTBS computation subtest tell similar stories; they differ only in the degree to which they separate mathematics CAI students from their CAI controls. Plots of normal curves derived from the standardized treatment effects for the CST and CTBS computation subtests are presented in Figures 1 and 2. Both plots show increasing separation over time between scores of users and non-users of the mathematics CAI curriculum. The CST data show greater gains than the CTBS data, consistent with earlier statements that the CSTs might represent an upper bound of true treatment effects.

The mean performance of mathematics-CAI students on the CSTs was at the 79th percentile of control students at the end of one year, at the 82nd percentile at the end of two years and at the 89th percentile at the end of three years. For the CTBS computation data mean performance levels of mathematics CAI students were at the 64th percentile of control students after one year, 71st percentile after two years and 76th percentile after three years.

The treatment effects for students in grades 3-6 on Concepts and Applications may be underestimates of the true effect in mathematics since the subtests were composed of word problems which required both mathematical and reading ability and the (within CAI) control groups in these analyses had received reading and language arts CAI. A separate but coordinated investigation into the solution processes of users and non-users of the mathematics CAI curriculum[7] found no differences between the two groups in their understanding of mathematics. However, the data from two-year and three-year studies presented here would seem to indicate that the CAI mathematics curriculum was helpful in increasing scores on the applications subtest and perhaps on the Concepts subtest as well.

Figures 1 and 2

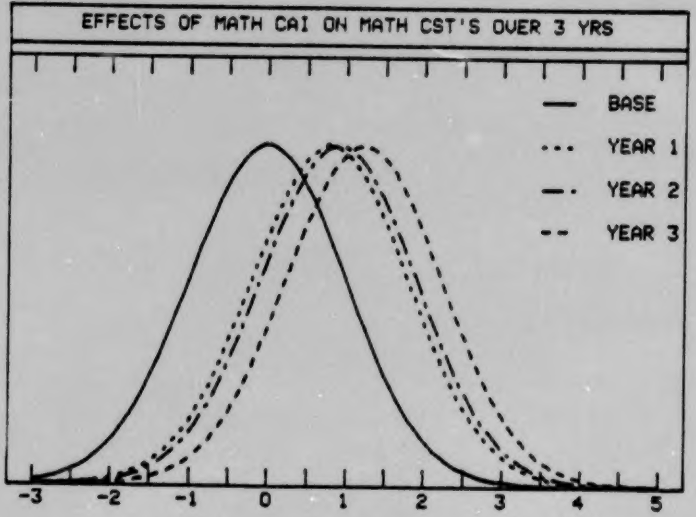


Figure 1

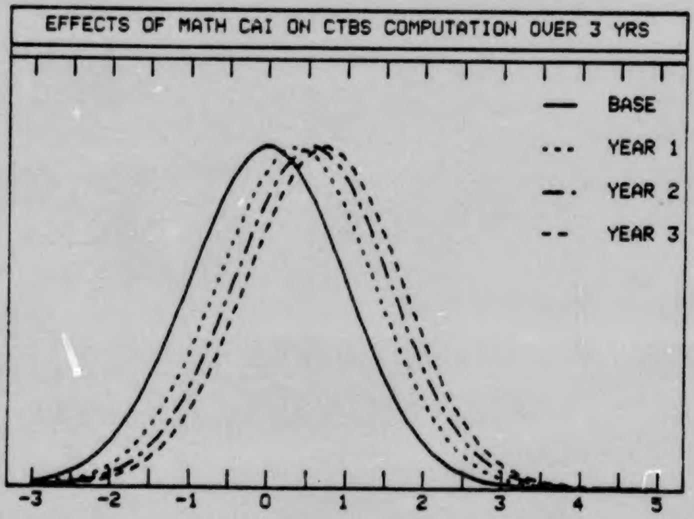


Figure 2

An additional pattern emerged from the longitudinal data for grades 4-6 where some students received two sessions of mathematics CAI (the MM group) while others received only one session (the MRL group). Treatment effects for the MRL group were about half the size of the treatment effects for the MM group both on the mathematics CSTs and the computation subtest of the CTBS.[8]

Overall, the mathematics strands curriculum performed very well. It adapted to students of all ability levels and provided effective drill-and-practice in mathematics computation. The effectiveness of the curriculum was demonstrated both in one-year studies and over two- and three-year periods. Increased amounts of mathematics CAI either within the school year or across school years were associated with higher test scores both on curriculum-specific tests and standardized tests.

Reading and Language Arts

The CAI reading curriculum used in this study was developed for students in grades 3-6 and contained a strand of basic sentences which purported to reach students at grade level 2.5. For the students in our study, those estimates were misleading. At grade 4 in year 1, many students assigned to the reading-language (RL) CAI treatment were transferred to the MM group because they were non-English-speaking, non-readers, or limited-English-speaking students who did not read English. Those students were then excluded from the analyses. It was clearly a drawback that accessibility to the reading drill-and-practice CAI curriculum was dependent on an ability to read relatively well. At the other extreme, in grade 6 the reading CAI curriculum sometimes proved to be too easy. A few students "topped out" of the reading curriculum (i.e., completed it) during the early rapid-motion phase in which the computer determines a student's initial ability level. A few students assigned to 2 sessions of reading daily topped out within a few months although, generally speaking, progress was very slow in the reading curriculum.

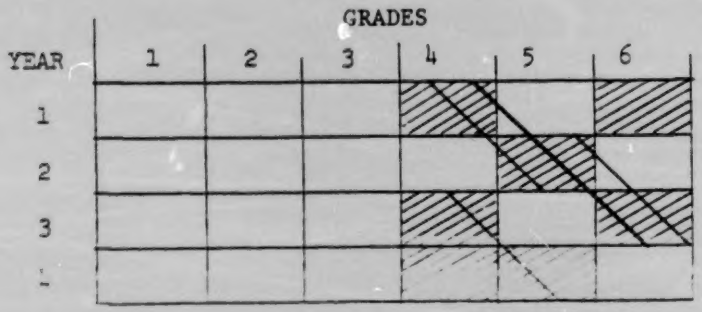
The language curriculum was designed for students in grades 3-6 and because its vocabulary was simpler than that in the reading curriculum it caused fewer problems of accessibility in the early grades. On the other hand, it caused more frequent problems in grade 6 with students topping out. Relatively large numbers of students who were assigned to 2 sessions of language CAI daily in the latter half of sixth grade topped out of the curriculum in the rapid motion phase and others topped out within a few months. Progress in the language curriculum was more rapid than progress in reading. For students interested in achieving, the more rapid progress was pleasing. Of the students assigned to both reading and language arts, most preferred the language curriculum because of the more rapid movement.

The length and breadth of the reading and language CAI curriculums did not purport to be as great as the mathematics CAI curriculum and perhaps this is less of a problem for the use of the curriculums in elementary schools than it was for the evaluation of the curriculums in this study. Schools, after all, do not generally assign students randomly to a CAI curriculum. However, there were--and are--limitations to the use of these specific reading and language curriculums even though they were the broadest available when the study started. Perhaps with newer technology a reading/language CAI curriculum could be built which would have the broad applicability (grades 1-6) that the mathematics strands curriculum enjoys.

Reading. Table 4 summarizes the one-, two-, and three-year studies of reading. Since the CAI reading curriculum was used only in grades 4-6, there were only seven one-year studies, three two-year studies, and one three-year study.

Table 4

The Reading Studies



On curriculum-specific tests of reading, the mean treatment effect for the seven one-year studies was .44 indicating that students exposed to reading CAI for one year averaged more than two-fifths of a standard deviation higher than students exposed to other CAI curriculums. The pattern of the seven scores, however, may be more enlightening than the mean. The treatment effects for grade 4 in all three years and for grade 6 in year 1 were all statistically significant and averaged .59. The treatment effects for grade 5 in both years and grade 6 in year 3 were not significant and averaged .29. The significant effects were obtained when students were exposed to reading CAI for the first time. In years subsequent to the first year of exposure, the reading CAI students continued to perform better than mathematics CAI students both on the pretest and posttest administrations of the reading CST but they did not increase their gains significantly. The three two-year studies showed a mean treatment effect of .52 while the single three-year study had a treatment effect of .42. Summaries of the mean CAI treatment effects for students receiving reading CAI are given in Table 5.

Table 5

Summary of the 1-Year, 2-Year, and 3-Year Studies of Reading CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Reading CST	8	3	1	.38**	.52**	.42	65	70	66
CTBS Vocabulary	8	3	1	.25**	.17	.58	60	57	72
CTBS Comprehension	8	3	1	.23**	-.01	-.24	59	50	41

** $p < .01$.

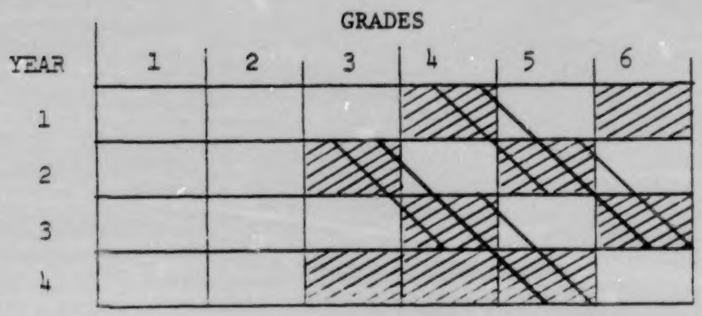
On the vocabulary and comprehension subtests of the CTBS, results were mixed. On the basis of the single three-year study, one might reach the conclusion that the vocabulary skills of CAI students improved over three years. But the data also seem to indicate decreasing ability of CAI students to deal with reading comprehension. Whether a consistent pattern failed to emerge because of some quality of the curriculum, the effects of the bottoming-out and topping-out phenomena on the research design, or some other factor, is not immediately obvious.

During the final year of the CAI study a newer reading-for-comprehension curriculum was evaluated along with the older reading curriculum. The newer curriculum resembled its predecessor except that a strand of paragraph comprehension had been added. Students who were assigned to the reading-for-comprehension curriculum did better than students assigned to reading, language arts or mathematics CAI both on the reading comprehension and on the language expression subtests of the CTBS.

Language. Table 6 summarizes the one, two and three-year studies of language arts CAI. There were 9 one-year studies, 4 two-year studies and 2 three-year studies.

Table 6

Language Studies



As was the case with the reading results, the CST treatment effects in the first year of the study were the largest obtained in the four years even though students had received only four months of CAI in that school year. However, all treatment effects in one-year studies involving the language CSTs were statistically significant for students receiving 10 minutes of language arts CAI daily. There was a greater differentiation between the MM and RL groups when tested on the content of the language curriculum than the reading curriculum. Mean CAI treatment effects for one-, two- and three-year studies of the language curriculum are presented in Table 7.

Table 7

Summary of the 1-Year, 2-Year, and 3-Year Studies of Language CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Language CST	10	4	2	.71**	.76**	.73**	76	78	77
CTBS Spelling	10	4	2	.14*	.05	.14	56	52	56
CTBS Mechanics	10	4	2	.22**	.27*	.25	59	61	60
CTBS Expression	10	4	2	.11	.05	.23	54	52	59

* $p < .05$.

** $p < .01$.

Mean treatment effects were averaged over 10 sets of data in the 9 one-year studies (RL or LL treatments), 4 sets of two-year studies and two sets of three-year studies. Although all the treatment effects were positive, they failed to show the pattern of increasing gains over three years demonstrated by the mathematics CAI curriculum. This may be due in part to the problems encountered in the random assignment of students to reading and language CAI curriculums. It may also be due to the fact that RL students in grades 4-6 received only half as much time in reading CAI or language CAI as the students received in mathematics CAI. For whatever reason, CAI students in the reading and language arts curriculums failed to demonstrate increasingly better test performance over multiple years. However, each of the verbally oriented curriculums did demonstrate an ability to help students improve reading and language scores as measured by curriculum-specific tests and by standardized tests.

In summary, each of the CAI curriculums proved its effectiveness although some curriculums performed better than others. The mathematics strands curriculum showed strong promise in longitudinal studies. The reading and language CAI curriculums had less breadth but were both capable of helping students to improve. Computer-assisted instruction as defined and used in this study was a powerful tool for increasing students' skills in mathematics, reading and language arts.

CAI Effectiveness: A Second Look[9]

Gene Glass evaluated the CAI study and its measurements, estimated the effects of added CAI and the effects of replacing some traditional instruction by CAI and, finally, compared the effectiveness of CAI with alternative methods of improving achievement.

He evaluated the usefulness of the various control groups in the same way as the primary investigators--relying most heavily on the within-CAI controls derived from the random assignment of students to CAI curriculums, considering the data from the cohort control studies useful despite their drawbacks, but rejecting the studies involving comparison schools. He evaluated the standardized-test data superior to the curriculum-specific test (CST) data in estimating true treatment effects.

Glass used meta-analytic techniques to estimate CAI treatment effects on the standardized tests. He analyzed the treatment effects from the randomized studies as effects of added CAI using the rationale that CAI students had equal exposure to whatever was taught in the classroom but differential exposure to CAI curriculums in the CAI lab. The effect sizes for 10-20 minutes of reading and language-arts CAI for one year ranged from a low of .15 of a standard deviation in spelling to a high of .45 in reading comprehension. For one year of mathematics CAI, treatment effects were estimated at 1/4 of a standard deviation for 10 minutes of CAI daily and 1/2 of a standard deviation for 20 minutes daily.

The effects of replacing part of traditional instruction by CAI were determined by a meta-analysis of several CAI vs. cohort-control studies. The treatment effects were, in general, slightly lower for the cohort-control studies with the largest effects occurring for mathematics computation (.45 of a standard deviation) and language mechanics (1/4 of a standard deviation).

Glass compared the CAI treatment effects with effects obtained using other intervention strategies: reduction in class size, tutoring, instructional television, teacher-training, and electronic calculators. While the effectiveness data from the alternative methods of instruction helped to place the CAI data in a slightly more informative context, no attempt was made to evaluate costs. Although the effectiveness of the mathematics CAI curriculum, for example, appeared to approximate the effectiveness of mathematics tutoring (the ultimate reduction in class size), the instructional method of choice should be the one which is most cost effective. Closure on the question of cost-effectiveness must await further analysis.

CAI: The Cost Study[10]

Given the study's focus on the educational needs of disadvantaged students, two questions arose pertaining to costs. The first question was based upon the assumption that funding for special educational services for disadvantaged students is derived primarily from special categorical aid for that purpose, such as that received under Title I of the Elementary and Secondary Education Act of 1965. Therefore, it is important to know if CAI can be provided within the budget that is available for these compensatory educational services for disadvantaged youngsters. Second, it is important to know if the CAI approach can improve the educational proficiencies of disadvantaged students at costs that are similar to or less than those associated with other instructional alternatives.

The first issue is one of cost feasibility. If the costs of this CAI approach exceed the funds available for instructional purposes for disadvantaged youngsters, it will not be within the boundaries of feasibility. The second issue is one of cost effectiveness. Even if CAI can be provided within the present budgets for compensatory education, it should be adopted only if it provides better results relative to its costs than do existing alternatives.

Cost feasibility was examined by Levin and Woo by estimating the replication costs of the CAI approach used in the ETS/LAUSD experiment, that is, the cost of replicating that system in other school settings. Costs were limited to those associated with the delivery of CAI while omitting costs that were tied uniquely to the experimental status of the present system.

Based upon the ingredients approach to cost analysis, it was found that up to three sessions of drill and practice of 10 minutes duration could be provided daily for each disadvantaged child at the 1977-78 level of Title I expenditures. This means that three different subjects could be provided, or that multiple sessions in one or two subjects could be offered, for each child. As such, it appears that the instructional strategy is cost feasible within present provisions for compensatory education. Utilizing one A-16 minicomputer to operate CAI labs in two schools increased costs rather substantially, but two sessions of CAI daily would still be feasible within 1977-1978 compensatory educational allocations.

Levin and Woo also estimated costs for the more advanced CCC-17 minicomputer system, and somewhat surprisingly the costs were in the same range as those of the older A-16. One 10-minute session of CAI daily over the school year was estimated to cost about $130. In part, this finding reflects the very heavy software component of CAI approaches, and, in part, it may reflect the possibility that the CCC-17 is more effective than the A-16.

In 1977-78 it cost about $100,000 a year to provide a classroom, personnel and equipment for servicing 32 terminals in a CAI laboratory using an A-16 minicomputer. A reported breakdown of cost into five categories is accompanied by percentages of funds expended for each category:

Facilities and equipment (including a classroom, computer, 32 terminals and printer)	36%
Personnel (including a CAI coordinator and two 3-hour teaching assistants)	35%
Curriculum rental (from CCC)	7%

Maintenance (contracts for computer, terminals and printer)	16%
Miscellaneous factors (supplies, insurances, etc.)	6%

More than one-third of the cost was associated with personnel.

It is clear that a more exhaustive analysis of the merits of different CAI approaches, as well as a comparison between them and other instructional strategies, will require effectiveness data as well as cost estimates. Given the data comparing the effectiveness of the current CAI approach with other intervention strategies, it is hoped that a cost effectiveness comparison can be made at some future date. The methodology for the cost-effectiveness study is included in the Final Report.

Perspectives on CAI from School Personnel[11]

The CAI program described in this summary was well received by most school personnel. Principals liked the program and often brought visitors to the CAI labs. Parents filled the lab during every open house and were enthusiastic supporters of the program. Teachers, students and CAI coordinators were most closely involved with the program. Their perspectives will be discussed separately.

Teachers' Perspectives

Initial acceptance of the CAI program on the part of teachers was less than wholehearted due, at least in part, to start-up problems with the equipment and interruptions to classroom organization by beginning the CAI program in mid-year. By the end of the first year some teachers were enthusiastic while others had reservations. By the time the study ended, most teachers supported CAI fully and were convinced of its benefits to students. There were occasional complaints of less-than-perfect performance in two areas: disruption of the classroom by the CAI schedule and dependability of the equipment. Even in these areas, ratings were much more positive than negative. Overall, the CAI program received very high ratings for being well-run, helpful, worthwhile, and successful.

Students

Students were very enthusiastic about computer-assisted instruction. They were not always enthusiastic about the specific assignment they received during the random assignment of students to curriculums, especially when that assignment continued for several years. Examples of the strongest negative responses from students when asked about the CAI program included the following:

> CAI is real boring, but I guess it would be better if I had reading or language, but I'm stuck with math.

* * * * *

> I dont think computers are very fun I know that I'm learning more than I would in my class aloan but I find CAI boring you keep on getting question after question I take only Math-M and would find CAI more interesting if If I could do some thing a little different once and a while. Truly, K.H.

Only 10-13 percent of student comments in any year were negative, however. Most students were strongly supportive of the program. The students speak for themselves without editorial assistance:

> I think that the Computer is fun and it can help you learn, and to be smarter in class. A computer is a machine that give you all the answers. A terminal is something that gets it questions from the computer A computer is a nice thing to have. It helps you in what you need to work on. And a Computer is like a teacher. It asks you questions and you answer it. I think a computer is more smarter than you are and it is smarter than anything.

* * * * *

> I think the computor is allmost the best class in this whole school. For one reason it helps you to understand things that you dont understand and it helps you to know things that you don't know. You want to know. One more thing is I like the teacher. They are very nice if you don't know something all you have to do is raise your hand and they will help you. I am very happy that we have computor in our school. I wish that we would have got it earlier. I'm also glad that we get to go everyday of the week.

* * * * *

> Computers is an exiting event, everybody is working and trying hard to get one hundred percent. It feels like we're a great big family, just doing our jobs, so I like computers even though sometimes I get a low score.

* * * * *

> I think the C.A.I. program is fantastic. I think the program should be spread through out every school system in America.

* * * * *

> Listen up and listen good....I like these computers becouse they help you learn new things, they....help you in lots of ways. I have math and Im good at it but I wish I could be in topics or reading. Now I have lots of friends that likes computers and if you take them away we will be disapointed. So you better not take them away.

Data on student attitudes derived from student questionnaires were evaluated in a separate study.[12] In that study a greater sense of internal responsibility for success was found among CAI students when compared to non-CAI students.

The CAI Coordinators

The CAI coordinators were the most enthusiastic supporters of the CAI program. Each one had had years of experience as a classroom teacher and became convinced that CAI was helping all students to improve their skills. At the conclusion of the study they had many success stories to report as well as a few failures. Where failures were identified, they were associated with school failures in general rather than CAI in particular. On the other hand, students who were not doing well in the classroom occasionally did quite well in the CAI lab. As a final statement, at the conclusion of the study the CAI coordinators agreed "It's a crime to have the CAI lab in use less than full time."

Implications for Schools

The ETS-LAUSD study has demonstrated the effectiveness of the CCC mathematics reading and language arts courseware used in a pull-out program of drill-and-practice CAI. The effectiveness has been demonstrated both in one-year and longitudinal studies. What does this mean to school administrators and school boards who have to make decisions about educational issues? Does this study become a strong endorsement for computer-assisted instruction? Why did the results in this study occur? Wherein lies CAI's effectiveness?

The Computer

The effectiveness of CAI in the Los Angeles study was dependent on the computer only to the extent that the computer was a reliable instrument for disseminating the CCC software. The computers used in this study were minicomputers, dedicated to running the CCC software. They are/were old-fashioned, outmoded, no longer sold through CCC. Nevertheless, despite the fact that they contained none of the accoutrements of newer and more sophisticated technology, they worked. And that is all that was necessary on the part of the computers in this study--that they should be reliable instruments directed by the CCC software.

The CCC Software

The success of CAI in the Los Angeles study was in a large part due to the CCC software. It was the courseware and the software necessary to manage the courseware that determined what students saw and responded to while they were in the CAI labs. Criticisms of the CCC software--that it, too, was old-fashioned compared to the possibilities associated with newer technologies--did not and could not negate its effectiveness as demonstrated in the study. The Mathematics Strands curriculum, in particular, demonstrated a remarkable power to increase the distance between users and non-users over the three years of the longitudinal studies.

The CAI Program

The success of CAI in this study may be due, in some part, to the way in which CAI was implemented. In each of the experimental schools a CAI lab was established, a highly qualified teacher was trained to serve as CAI coordinator in the lab, and a CAI program was implemented whereby students attended the lab daily for one or two 10-minute sessions of CAI. Standards of behavior in the CAI lab were established early and maintained; behavior problems were less apparent in the lab than in general. The atmosphere of the CAI labs was cheerful and work-oriented. Tight operating schedules were developed in order to accommodate the many students and the schedules were maintained because of student/teacher cooperation. The CAI program was a friendly and business-like enterprise, consistently well run. The CAI coordinators and teaching assistants--and any adult who was present in the CAI lab--helped answer students' questions.

Motivation was enhanced by contests among classrooms for the highest number of students with 80% or more correct responses.

Teachers had minimal responsibility for the success of the CAI program but had the opportunity to select the schedule which best fit their classrooms. In the small schools with only 16 terminals in the CAI lab, teachers remained in their classrooms with half of their students while the other half went to the lab. Teachers selected the groups of students to go to the CAI lab on the basis of the teacher's classroom schedule, since the computer could handle any student in any curriculum at any time. The same procedure was followed with some upper grades in the larger CAI schools. That arrangement provided teachers with two periods of time daily when the teacher/pupil ratio was half its normal size. In the larger Title I school where transportation to and from the CAI lab might cause problems, teachers often elected to bring the whole class to the CAI lab at the same time. Wherever it was possible, teachers in grades 1 and 2 were encouraged to bring the whole class to the lab so that extra help could be provided to very young students. CAI schedules were made up by the CAI coordinator with input and cooperation from the classroom teachers.

How can the findings of the study be generalized? Are other kinds of CAI likely to be more or less effective? These issues are a matter for serious concern. Generalizability of the effectiveness data is possible only to the extent that components of the Los Angeles CAI program match components of other configurations of CAI. In fact, many of the components of the Los Angeles CAI program can be described in terms of the findings of school effectiveness studies having nothing to do with CAI.

Components of Effectiveness

In mastery-learning studies, a criterion-referenced test is given at the end of each learning unit. The test determines which students have mastered the unit and which need more help to achieve mastery. Students provided with feedback and extra time and help obtain the skills necessary for subsequent learning tasks. Studies comparing mastery-learning classes with conventional classes have demonstrated the superiority of mastery-learning (Bloom, 1974).[13] In the CAI study, the software which drives the CCC courseware determines the initial mastery-level of each student in each strand of the curriculum, places the student at the appropriate entry level, and allows the student to progress within the strand only upon mastery of material.

Academic learning time (ALT) is defined as the time a student is engaged with academic materials or activities that yield a high success rate wherein a student understands the task and makes only occasional errors. A major finding of the Beginning Teacher-Evaluation Study, BTES (Berliner, 1979),[14] was that increases in ALT are associated with increases in student achievement. Because the CCC software adapts the entry level in the CAI curriculum to the ability level of the student and allows the student to progress only upon demonstration of mastery, a student using the CCC curriculums has a high probability of success during each and every CAI session.

Early analyses from the BTES (McDonald & Elias, 1976)[15] indicated that direct instruction improved student learning. Direct instruction was defined as having three components: (1) a component that explains what is to be learned or models it or elicits its elements by questioning (italics ours), (2) a component that provides the appropriate conditions for attempting what is to be learned, and (3) a component that provides feedback on how well the child is learning the task. The CCC courseware elicts by questioning; the software assures mastery of preceding elements before attempting further work; immediate feedback is given to every student response and, for the benefit of both students and teachers, the standing of each student within each strand of the curriculum is available at any time.

Apart from the CAI curriculums, themselves, the CAI labs demonstrated qualities that were found to be effective in other studies. Adaptability and consistency of instruction were directly related to instructional efficiency in a study of successful schools (Venezky & Winfield, 1979).[16] Use of the CAI labs was a consistent pattern for most CAI students who received 10-20 minutes of instruction over periods up to 4 years. Although as many as 32 students were in the CAI lab at any one time, the CAI curriculum level covered a broad range, adapting to the ability levels of the students.

After reviewing others' research as well as his own, Edmonds (1979)[17] summarized the characteristics of effective schools as having (1) strong administrative leadership, (2) climate of expectation of achievement, (3) an orderly quiet atmosphere, neither rigid nor oppressive, (4) a belief in the importance of student acquisition of basic skills, and (5) frequent monitoring of student progress. The CAI labs in the study were run by CAI coordinators who were, themselves, strong teachers and good program leaders who ran the bright and cheerful labs in a business-like way and monitored student progress in basic-skills areas.

Gage (1978)[18] developed a set of inferences for maximizing student achievement in third grade from a study of the research.

--Teachers should have a system of rules allowing pupils to attend to personal and procedural needs without having to check with the teacher.

--Teachers should move around the room a lot, monitoring pupils' seatwork and communicating to their pupils an awareness of behavior while attending to academic needs.

--For independent pupil work, teachers should insure that assignments are interesting and worthwhile yet easy enough to be completed by each pupil alone.

--Teachers should keep to a minimum activities such as giving directions and organizing class for instruction.

--Teachers should call on a pupil by name before asking a question as a means of insuring that all pupils are given an equal number of opportunities to answer questions.

--With less academically oriented pupils, teachers should always aim at getting the child to give some kind of response to a question.

--During reading-group instruction, teachers should give a maximal amount of brief feedback and provide fast-paced activities of the "drill" type.

All seven of the inferences describe the conditions in effect in the CAI labs in Los Angeles. Although teachers did not call upon students by name, all students were exposed to--and responded to--many questions during their CAI time. One diligent second-grader answered 102 questions in a 10-minute session. A response to 40 or 50 questions was more typical. The CAI coordinators moved about the lab, answering students' questions and monitoring their work. Behavior problems were minimal because of the system of rules and expectations for behavior in the CAI lab.

The success of CAI in this study may be related to the successful practices identified in other effectiveness studies: mastery learning, high academic learning time, direct instruction, adaptability and consistency of instruction, an orderly atmosphere with expectation of success in basic skills, the use of drill, and equal opportunity for responses from all students with a high probability of success in responding. The advantage of the computer for drill-and-practice activities lies in the computer's efficient use of time. For only 10-20 minutes daily, truly individualized drill-and-practice can be used to instruct students at their own ability levels, to provide immediate feedback to each response, to move students ahead on the basis of their mastery of subject matter, to keep records of each students' placement in each strand of each curriculum, and to do this with demonstrable effectiveness over a period of years.

CAI Effectiveness and Microcomputers

The present study produced its effects with the use of a CAI lab equipped with a minicomputer dedicated to running the CCC curriculums. With the tight budget constraints and improved technology of the 1980s, an increasing number of school systems are purchasing microcomputers for computer-assisted instruction in elementary schools. Can the results of this study help to predict the effectiveness of CAI using microcomputers? Consider, again, the three major components of the study:

The CAI lab. Microcomputers are sometimes used--one or two at a time--in a classroom, or in hallways or closets adjacent to the classroom, under the supervision of the classroom teacher. To the extent that these conditions prevail, there exists a very real difference in the operation of CAI. In the present study, either the total class received drill-and-practice CAI for 10-20 minutes in the CAI lab or the teacher selected a group of students to attend the CAI lab at one period of time with the rest of the class attending at a later time. Teachers electing the later option had two periods of classroom time, usually back-to-back, with a considerably reduced teacher-pupil ratio. In neither case was the classroom teacher responsible for knowledge about the computer or monitoring student use of it. Even when microcomputers are used in a resource room attended by students needing remedial work, the conditions are usually different in that only one or two students at a time are withdrawn from the classroom. Where schools utilize multiple microcomputers in a network, or cluster configuration, the learning environment would be most analogous to the minicomputer CAI lab.

The minicomputer. Differences between the storage and memory capability of minicomputers and microcomputers are becoming less and less apparent with current technological advances. At present, however, low-cost mass storage devices for microcomputers are not large enough to accommodate a complete set of CAI programs such as CCC's mathematics CAI curriculum without customized adaptation. The decreasing cost of the microcomputer and its capabilities with regard to sound and graphics have made it a very attractive tool for education. However, in the long run it is not the computer hardware but the educational software which is important to computer-assisted instruction.

The CCC curriculums. The major component of any CAI program is the courseware itself. What students practice--and what they learn--depends on the curriculum. In this study, there were differences among the mathematics, reading and language arts curriculums in the length and breadth of coverage, accessibility by students of different ability levels, and effectiveness over periods of one year or more. Even greater differences can be expected among the myriad smaller CAI programs developed by hundreds of different authors. Because of the reduced storage capacity of the microcomputer, CAI courseware similar to the CCC mathematics curriculum faces major changes when adapted for a microcomputer. Those changes--breaking up the curriculum into component parts for example--create a CAI program quite different from the program evaluated in the current study. Microcomputer drill-and-practice courseware may or may not be graphically more attractive, slower in operation, more self-paced and self-selected, and more narrowly focused within each CAI session. Whether the changes potentially increase or decrease the effectiveness of a mathematics CAI program is a question for future research to answer.

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COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY:

A DESCRIPTIVE STUDY

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Chapter I

INTRODUCTION TO THE STUDY

In July, 1975, the Educational Testing Service (ETS) and the Los Angeles Unified School District (LAUSD) jointly submitted a proposal to the National Institute of Education (NIE) to provide funding for a study of the long-term effectiveness of computer-assisted instruction (CAI) for compensatory education. Existing evidence strongly suggested that CAI of the type to be studied--drill and practice in reading, language arts, and mathematics--was effective for periods of at least a year, that its costs were well within typical compensatory education budgets, and that, unlike many other apparently effective compensatory interventions, its use could easily be replicated. The ETS/LAUSD proposal requested funds to validate these earlier findings and to examine whether CAI's contribution to student performance could be maintained over periods as long as four years.

On March 15, 1976, the NIE funded a research design phase for this CAI project and on September 10, 1976, formally committed funds for the first year of the project's activities. From September 1976 through June 1980 the Los Angeles Unified School District operated four CAI labs under a subcontract with ETS. After a final year of data analysis and writing at ETS, the project ended in September 1981. This final report is an attempt to systematize what was done and what was learned during more than five years of study. In this section of the report the focus will not be on the statistical analyses of the data, but on a description of the project and its impact on people. In order to help the reader under stand the project better, discussion in this chapter will focus on the setting in which the study occurred and the CAI curriculums which were used.

The Setting for the Study

Several schools from Area 4 of the Los Angeles Unified School District were involved in the Study: four as CAI schools, two as comparison schools, and several others as occasional participants. Brief descriptions of six of the schools follow.

School 1

School 1 was located one block from the beachfront, in an area containing shops and apartments of all sorts. One side of the main thoroughfare boasted all of the symbols of new affluence while the other side maintained an atmosphere of counter-cultural bohemia. This school was the smallest in the study. The school building was modern, small, and neat, with touches of permanent art work inside and out. The school population was primarily Anglo and was highly transient.

During the third and fourth years of the study, a court-approved desegregation plan saw School 1 become part of a triad of schools in which School 1 served all fourth graders in the triad and the other schools served fifth graders or sixth graders. The plan worked well for integration and had both positive and negative impacts on the CAI study. Longitudinal data involving fifth and sixth graders at School 1 were lost, but two large one-year studies at the fourth-grade level were improved because of School 1's larger population. School 1 had no computer for the first three years of the study but was able to operate a small CAI lab as a sattelite of the computer at School 2. During the final 1979-80 school year, a CCC-17 computer was used at School 1 to run an up-dated reading-for-comprehension curriculum together with the older mathematics and reading curriculums.

School 2

School 2 was also small, but larger than School 1. It was located in a well-kept residential area. The population it served was quite diverse economically and socially. The ethnic composition of the student body was roughly half Hispanic and half Anglo, with a few others. Although the student transiency rate was moderately high, there was very little turnover in staff. The school building was modern in design, consisting of a number of buildings connected by covered walks.

School 2 was largely unaffected by the LAUSD desegregation plan since it was already integrated. It's small CAI lab contained only 17 terminals but its computer served the 15 terminals at School 1 as well. In addition to the regular students involved in the study, the CAI lab at

School 2 served a small population of aphasic youngsters and a group of Hispanic adults learning English.

School 3

School 3 was very large. It was situated in an inner city area a few miles southwest of downtown Los Angeles. The school was located on a short side street between a main surface road and a freeway. It consisted of three two-story buildings connected by walkways. Some rooms had exterior doors; others opened onto hallways; all doors except the office door were kept locked at all times. Except for a number of Hispanic children, the school population was Black. The transiency rate among students was extremely high. School 3 was a Title I school.

During the last two years of the study, the LAUSD desegregation plan provided that 50 fifth and sixth graders from School 3 attend a mid-site school, together with students from the Valley. The plan was successful in integrating a few students from School 3, but the school itself remained racially isolated. The plan caused a loss to the study of students in both longitudinal CAI cohorts and cohort control groups. School 3 had a full-size CAI lab with a computer and 32 terminals.

School 4

School 4 was a Title I school located in an older residential area. The school building was of the traditional style--a two story structure with wide interior hallways. The student population was ethnically mixed, predominantly minority with a growing number of Hispanic students. The school had a large CAI lab with a computer and 32 terminals.

School 4 was untouched by the LAUSD desegregation plan during the years of the CAI study. It remained a racially isolated school. Complications in testing the Hispanic population in the final years of the study together with a high transiency rate reduced the number of students available for longitudinal studies.

School 5

School 5 was located on a main traffic thoroughfare. The stores across the street from the school had their front doors locked and could be entered only from the parking lot in back. The school itself was entered from a side street. The main school building was old, designed like a Spanish mission, and temporary classroom buildings were situated in the schoolyard. The halls were decorated with students' art and craft work. Approximately two-thirds of the students were Hispanic and one-third were Black. School 5 was a Title I school. It contained no CAI lab but its students participated in the study's testing program. It was a comparison school.

School 6

School 6 was situated on a quiet street in a very neat residential area. It was a large school, modern in design, consisting of a number of buildings along three sides of a large school yard. The school population was predominanatly Hispanic, but a great variety of ethnic backgrounds were represented, including more Oriental children than in any other school in the study. School 6 lost its Title I standing just before the CAI study began. It was a comparison school and had no CAI lab.

CAI Curriculums

In searching for CAI curriculums it became obvious that there were no reading or language curriculums immediately available which could be offered to students across grade levels 1-6. Computer Curriculum Corporation (CCC) could provide Reading, Grades 3-6 and Language Arts, Grades 3-6, but lack of audio signals on their systems precluded offering a curriculum for beginning readers. CCC could also provide Mathematics Strands, Grades 1-6 in the same software package as their reading and language programs. The decision was made to use these off-the-shelf curriculums for several reasons:

(1) They were CAI curriculums which were immediately available, having had fairly wide usage in systems located across the United States.

(2) The CCC curriculums--especially Mathematics Strands--had a body of evaluation studies which, although they had shortcomings, appeared to indicate success in raising test scores.

(3) CCC was the only vendor which could offer all three curriculums in one software package, at a price the study could afford. Having one software package assured the study of a minimum amount of time to get the CAI operations running.

The CCC curriculums are drill and practice curriculums which are not intended to teach students but to reinforce the skills they have already been taught in the classroom. A description of each of the curriculums follows.

Mathematics Strands, Grades 1-6

Mathematics Strands, Grades 1-6 is one of the most highly individualized CAI (computer-assisted instructional) programs ever developed. A student participating in the Mathematics Strands program receives lessons that are prepared for her on the basis of her own achievement and educational needs. Her lessons are not stored in the computer's memory but are generated by the computer as she works at a terminal. Because the computer immediately checks the student's response to each item, it can adjust the lesson's difficulty level while the lesson is in progress. Furthermore, it can make this adjustment in each concept area on which the student is working. Such individualizing capability represents a significant step forward in the development of curriculum material that meets the goals of individualized instruction.

All the topics in elementary school mathematics, with the exception of geometry and word problems, are included in the Mathematics Strands program. Its stress on basic computational skills makes it compatible with a wide range of textbook series. Because it does provide individualization, the program is appropriate for both remedial and accelerated classes.

The Mathematics Strands program achieves its goal of individualized instruction by using a strands structure. There are fourteen strands, one for each concept area included in the program. The strands are:

Strand 1	Number Concepts
Strand 2	Horizontal Addition
Strand 3	Horizontal Subtraction
Strand 4	Vertical Addition
Strand 5	Vertical Subtraction
Strand 6	Equations
Strand 7	Measurement
Strand 8	Horizontal Multiplication
Strand 9	Laws of Arithmetic
Strand 10	Vertical Multiplication
Strand 11	Division
Strand 12	Fractions
Strand 13	Decimals
Strand 14	Negative Numbers

During every session, the student receives a mixture of items from all the strands that have exercises at her grade level. The student's work in each of the fourteen strands is individualized to meet her educational needs. In addition, the computer adjusts the proportion of exercises from each strand to match the proportion of exercises covering that concept in an average textbook.

Reading, Grades 3-6

Reading, Grades 3-6 offers a supplemental reading program with two important features: a high degree of individualization, and a means of diagnosing class and individual reading weaknesses. Both these features make the program a useful tool in building toward the goal of individualized instruction.

The program consists of practice items designed to sharpen the student's reading skills in five areas: word analysis, vocabulary extension, comprehension of sentence structure, interpretation of written material, and development of study skills. It contains enough material for four years of work at grade levels 3, 4, 5, and 6, as well as supplementary remedial material that extends to grade level 2.5.

Each student moves through the program at his own pace. The difficulty of the material he receives is tailored to his own achievement level and is not affected by the performance of other students in the class. If a student needs remedial work, the program moves him to a lower grade level. If a student needs to advance to more challenging material, the program moves him forward rapidly. The students in a given class may spread in grade placement over every grade year the program covers.

The program uses a strands structure to individualize each student's lessons. Each of the five skill areas the program includes is represented by a strand, or graduated sequence of related items. The strands are:

Strand A	Word Attack
Strand B	Vocabulary
Strand C	Literal Comprehension
Strand D	Interpretive Comprehension
Strand E	Work-Study Skills

A student who is doing very well in one area moves forward rapidly in the strand which contains items from that area. One who is performing poorly in one area is moved back in that strand until a level is reached that is suited to the student's abilities. At this point forward motion begins again. The rate of movement in each strand is not affected by position or rate of movement in the other strands.

The program was designed with low reading levels in mind. It begins with very simple vocabulary and adds words from carefully selected vocabulary lists. The lists concentrate on words that children encounter in reading materials and daily life situations.

A special section at the lowest levels of the program contains basic two- to five-word sentences. It is included as remedial work for those students in any school grade who may need it. The material in this section is not differentiated into strands.

Language Arts, Grades 3-6

Language Arts, Grades 3-6 attacks today's most common language usage problems. It covers grades three through six with enough material for a year's work at each grade level. In addition, it offers supplementary material designed for students with special language problems: hearing-impaired students and students for whom English is a second language.

Language Arts, Grades 3-6 supplements almost any language arts textbook or teaching method. It stresses usage instead of grammar and uses very few grammatical terms. Students using the program learn by example, pattern, and practice.

The program has two sections, strands and topics. In the first year of this study, only the strands section was used. The strands section supplies individualized drill and practice tailored to each student's achievement level. In the topics section, students receive lessons on a topic assigned by their teacher.

The strands section consists of eight strands, or strings of items. Each strand covers grades three through six. The program keeps records of each student's performance in every strand and uses this information to adjust the student's level in each strand.

THE STRANDS

Strand A	Principal Parts
Strand B	Verb Usage
Strand C	Subject-Verb Agreement
Strand D	Pronoun Usage
Strand E	Contractions, Possessives, and Negatives
Strand F	Modifiers
Strand G	Sentence Structure

Summary

Chapter I described the six Los Angeles schools most relevant to the study together with some of the forces which impacted on the schools over the life of the project. Also described were the three drill-and-practice CAI curriculums used in the study: Computer Curriculum Corporation's Mathematics Strands, Reading and Language Arts. We now turn to the acquisition and operation of the CAI systems.

Chapter II

ACQUISITION AND OPERATION OF THE CAI SYSTEMS

This chapter will describe how the three CAI systems were acquired, what problems existed, how the CAI coordinators were trained and, finally, how the CAI program worked. Main topics are (1) early preparations, (2) the initial shakedown period, and (3) routine operations.

Early Preparations

The Los Angeles Unified School District entered into a subcontract with Educational Testing Service in the latter half of September 1976. Even before the subcontract was signed, LAUSD was engaged in project activities on two fronts: summer training for coordinators and plans for building modifications. With the signing of the subcontract, the procedures leading to the acquisition of CAI equipment were initiated.

Summer Training

From June 21 through August 6, 1976, the ETS project director attended the summer training workshop for CAI coordinators and their alternates. Work accomplished during the workshop included:

Observations. Coordinators and alternates were able to observe students working with the CCC curriculums and supervisory personnel performing many of their day-to-day responsibilities in three schools in the Los Angeles area.

Hands-on-experience. Coordinators and alternates were entered and enrolled in the Mathematics, Reading and Language Arts curriculums from CCC. The coordinators and alternates spent major portions of several days becoming acquainted with those curriculums both through hands-on experience and reference to the manuals for the curriculums.

Preparation of materials. The ETS project director, the LAUSD professional expert, the coordinators and alternates worked on the preparation of several products for use in the project. As part of their hands-on experience, the coordinators prepared progress tests at six levels of difficulty in mathematics and four levels of difficulty in reading and language. These tests provided the basis for the curriculum-specific tests recommended by the Advisory Panel for administration to all students in the project. Coordinators and alternates also prepared materials for a project handbook containing information on the research design, project activities, suggestions for workshops, schedules of classes, random assignment of students to treatments and other topics relevant to the success of the study. Finally, they produced material for handouts to parents, teachers and visitors.

The summer workshop helped to develop strong rapport among the participants, increasing both the chances of successful adherence to the research design and the enjoyment by the participants of their roles in the project.

Building Modifications

Blueprints for building modifications were begun in the summer of 1976 according to sketches in Appendix G of the Research Design presented to NIE and the Advisory Panel in May, 1976. Before the summer was over, changes in the building plans were requested. Specifically, the coordinators asked that computer rooms NOT be subdivided by walls into three sections as planned, but that the openness of the classrooms be preserved. Again, the plans for overhead room air conditioners were revised to window air conditioners when installation time was considered a major factor in delaying the start of the study. Implementation of the final blueprint plans began in the fall.

LAUSD personnel sealed doors from the computer rooms to adjoining classrooms. They removed unnecessary bulletin and chalk boards and removed a sink in one classroom. They moved cabinets and installed wooden counters on which the CAI terminals would be placed. They wired the computer rooms and built enclosures for the new wiring. They modified windows for air conditioners and installed two window air conditioners in each room containing an A-16 computer. Finally, they painted the CAI rooms and varnished the furniture. This work was completed by November 15, and the rooms were ready at that time to receive the CAI equipment. Further work would be necessary (e.g., installation of intrusion alarms, phones, etc.), but the major changes prerequisite to the onset of CAI in the schools were completed.

Purchase and Installation of Equipment

Bidding for the purchase of CAI equipment could not begin until the contract between NIE and ETS and the subcontract between ETS and LAUSD were signed. At that point the bids were let in three parts: one for the purchase of three computers, one for the purchase of 100 terminals and four printers, and one for communications equipment (modems and multiplexors) for use between School 2 and the satellite school, School 1.

Part I. Computer Curriculum Corporation (CCC) won the first bid and supplied three A-16 computers to LAUSD. Delivery of the three computers occurred between November 19 and 23. Four terminals were loaned to the schools, and an in-service for coordinators was conducted by CCC the following week. CCC also supplied the software to deliver the Mathematics Strands, Reading and Language Arts curriculums. CCC's successful bid reflected the following costs:

Hardware:	3 A-16 computers		$204,360.
Software:	Mathematics Strands	$214/mo x 3	
	Reading	$213/mo x 3	
	Language Arts	$213/mo x 3	
	$1920 x 12 months		23,040.
Tax (6%)			13,644.
Installation (maximum)			9,000.

Part II. The David Jamison Carlyle Corporation won the bid to supply 100 terminals and four printers. LAUSD, by law, is required to work in a competitive bidding environment which allows for practically no deviation from published procurement conditions. Unfortunately, two protests were filed on earlier terminal bids based on minor technicalities. Rather than risk legal action with its attendant lengthy delays, it was decided to rebid the terminal procurements. Delivery of 50 terminals was contractually called for before year-end, and the remainder were to be available prior to January 10. In fact, all terminals were delivered by the end of December. The acceptable bid reflected the following costs:

100 terminals	$143,995.00
4 printers	7,799.80
Tax (6%)	9,107.69
Delivery	1,800.00

Part III. Computer Curriculum Corporation won the bid for the communications equipment. Their bid reflected the following costs:

2 Modems	$4,710.00
2 Multiplexors	7,550.00
Tax (6%)	735.60
Installation	200.00

Modems and multiplexors were delivered to Schools 1 and 2 just before Christmas vacation. Noise on the phone lines between the satellite school and the computer caused communication problems. After several consultations with General Telephone personnel, the problems appeared to be resolved January 12.

All systems were up and running the week of January 10, and students in all four schools started computer-assisted instruction that week. It was a false start for students at Schools 1 and 2, however, since start-up problems plagued those schools especially. The next section covers some of the difficulties encountered in the initial shakedown period.

The Initial Shakedown Period

Conventional wisdom leads one to expect problems in setting up a CAI system. A small amount of research into problems encountered by others using the CCC systems had encouraged project personnel to believe those problems might not exist. Experience gave us mixed results with the project's three systems.

System Problems

Schools 1 and 2. The computer in School 2 ran the CAI operations in School 1, a satellite school, as well as CAI operations in its own school. Modems and multiplexors in each school allowed the CAI system to operate over phone lines between the schools. School 1 operated with 14 terminals; School 2 with 17. The situation in these schools during the initial shakedown period can best be described in the words of one of the coordinators:

> The sorrows of start-up begin with not starting up. One day of real work with children and the computer goes down. Mechanical problems, unanticipated and seemingly unavoidable, keep recurring. There is nothing sadder than the face of a child whose number and name have been rejected by the computer.
>
> The real problem seems to be that there is no one person ready to assume the responsibility for getting the bugs out. You call CCC who suggests calling Cincinnati Millicron who suggests calling Hazeltine who suggests calling General Telephone who suggests... etc., etc. All are very polite, very sympathetic--and very ineffective.

A new computer was shipped to School 2 and remained there, crated but ready, for several weeks. By mid-February, when school personnel were just about ready to give up hope--and, indeed, just at the time the system was to be inspected by the funding agency and the Advisory Panel for the study--the CAI system began to operate with its customary good behavior. School 2 had few problems after February, but School 1, the satellite, experienced some interference due to noise on the phone lines.

School 3. The CAI system at School 3 experienced the least difficulty. The A-16 computer was delivered before Christmas; the terminals arrived during Christmas vacation. The system was up and running by January 3 with only minor work needed on a few terminals. School 3 waited one week for the other CAI systems to be ready, then began the CAI program on January 10. The computer at School 3 was the first to pass an acceptance test and continued its good performance through the end of the year.

School 4. The CAI system at School 4 was only slightly more troublesome than the system at School 3 when it was set up. The CAI program was initiated on January 10, only one week after the end of Christmas vacation. However, minor problems kept interfering with a smooth implementation of the program. Late in January the problems increased and continued through mid-February when a gigantic effort by all vendors produced results. Subsequent problems were minimal. The coordinator at School 4 kept a log of her experiences during the first year of the study. The log reflects the joys and frustrations of implementing the CAI program in her school. The log is included as Appendix A.

Initial Acceptance

The advent of a new program in any school is likely to get a mixed reception. In principle, the idea of CAI was accepted whole-heartedly for the most part. On the other hand, the program called for several hours of pretesting--never a favorite occupation for teachers or students. Meetings were held at each school to explain the project and the CAI program to teachers and parents. The CAI coordinators accepted the responsibility for public relations activities and did a remarkable job in having the program accepted. They worked hard to prepare in-service training for teachers, to give them hands-on experience with the computer, and to provide opportunities for teachers to observe their students on CAI. There were some complaints, however, and these revolved around the issues of dependability, interference, and effectiveness.

Dependability. The acceptance of the CAI program was certainly related to the dependability of the system. In those schools which experienced little difficulty starting up the system, teachers' attitudes were more accepting than in the schools where teachers' expectations about the CAI schedule were constantly thwarted. At the end of January, 1977, the morale of coordinators and teachers in three of the four CAI schools was very low. By the end of February, however, when the systems were operating with a minimum of difficulty, morale improved.

Interference. At the time when CAI was introduced into the schools, teachers had well established classroom schedules. Even though the CAI program had been scheduled early in the school year, its midyear implementation caused shock waves in familiar classroom routines. After adjusting to the new program, most fourth- and sixth-grade teachers were enthusiastic. They even looked forward to the two periods in the day when the teacher/pupil ratio was reduced. With half the class at CAI, remaining students could get more individualized instruction. For some teachers, however, the CAI schedule proved to be an interference rather than an aid. This was particularly true for second-grade teachers.

Since second-grade students had been randomly assigned to greater or lesser amounts of Math CAI, treatment groups had been created which had no relationship to the groupings within the classroom. The CAI group receiving 10 minutes (later, seven minutes) of CAI was not out of the classroom long enough for the teacher to accomplish anything with the remaining students. Only teachers of mixed grades (1 - 2 or 2 - 3) reported little difficulty with the second-grade schedule. One school solved the problem by having the second-grade teachers come to the CAI room with their students, returning to the classroom with the group that finished first. Two teachers who had been opposed to the program became staunch supporters under the new schedule.

Effectiveness. Some teachers regret the existence of ever-increasing numbers of pull-out programs which seem to interfere with their job of teaching. Such teachers can be won over to a program only by awareness of the program's effectiveness. Feedback from ETS on student progress within the CAI curriculums increased the enthusiasm of some teachers for CAI and also helped to identify students with difficulties.

Routine Operations

After the initial shakedown period, the CAI program developed into a smoothly running operation. With a minimum of system problems, coordinators and aides were free to improve schedules, help students, provide information to teachers and develop routines for dealing with computer room tasks. Students settled into the system also. The final sections of this chapter deal with the routine of the CAI room.

The Coordinator's Day

The coordinator and her teaching assistants shared tasks such as housekeeping, care of the computer and terminals, helping students, and interaction with teachers. At the beginning of the day the computer had to be turned on and reloaded and the date advanced. Terminals also were turned on and made ready for students.

As the computer room day began, students arrived on their own or escorted by the teaching assistants. When students received 20 minutes of CAI--usually those in the upper grades--every 25 minutes or so a new group of students arrived in the lab. Younger students arrived every 15 minutes. While students were at the terminals, CAI personnel responded to repeated requests for help with problems and answers to questions. Attendance was taken. Sometimes notes were taken for teachers regarding help needed by individual students. Incentives were developed to motivate students to better performance.

At the end of the day, new students were enrolled, a backup tape was run, teacher reports were prepared and, finally, the computer was shut down.

The Student's Routine

Students learned very quickly how to use the CAI terminals. First graders were initially fairly slow at signing on--taking a minute or two rather than a few seconds. After a week or so most of the first graders were able to function efficiently. Older students learned almost immediately and, except for forgetting their numbers, were able to sign on and begin work with no delay. A fourth grader describes the procedure:

> When I go to the computer room we have to line up at the door and wait for a while and then we go in. When I firt, (sic) get in I put in my number and name which is 1174 and then a space and then my name. After all that I start working. I like the computer room because it makes me learn more math, language, and reading and it makes me use a pencil less.

Students often answered as many as 40 or 50 questions during one 10-minute session. As soon as one session was over, students receiving 20 minutes of CAI signed in for the second session. At the end of 10 or 20 minutes, students returned to their classrooms.

Summary

In this chapter we have described the early preparations for the CAI project: summer training for CAI coordinators, the building modifications for the CAI labs, and the purchase and installation of the CAI equipment. The initial shakedown period was described, when CAI systems were experiencing start-up problems and the initial acceptance of the programs was less than perfect. Finally, the routine of the coordinator's day was presented, together with a description of the student's activities in the lab. We now turn our attention to CAI from the perspectives of those who worked with it.

Chapter III

PERSPECTIVES ON THE CAI PROGRAM

For four years selected students in four CAI schools received from 20-100 minutes of drill-and-practice CAI each week. During that time CAI coordinators worked with half of the children in each school each year. For four years teachers either sent their students to the CAI lab or brought them, and each teacher had the opportunity to observe CAI in action. Each year students and school personnel were asked to report about CAI. Students, teachers and principals were interviewed; student writing was requested; and coordinators attended a debriefing conference each year. In this chapter CAI will be summarized by the people who participated in the study. Coordinators will describe successful and unsuccessful students in the CAI program. Students themselves will tell how they felt about CAI. The results of interviews with teachers and principals will be presented.

Successes and Failures*

At the end of the study, the CAI coordinators were asked to write, among other things, a brief description of the students they felt represented their successes and failures with CAI. Their case studies are presented in this section. In School 1 the CAI coordinator made the following reports:

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*Thanks are due the following people for providing the information for this section: Mary King, Marge Lord, Judy Newman, Ann Vasilopoulos, and Rayma Wells.

Bruno did poor work in his regular fourth-grade classroom but scored second highest in the school in the mathematics CAI curriculum. The last report showed his yearly gain to be 2.1 years and his average placement at the end of May was 5.6. Bruno took great pride in his daily scores and his classmates encouraged him to work hard to help their team in competitions. He asked for very little help--only when a new type of problem appeared in his lesson.

* * * *

Eva began CAI as a disinterested participant. Her attendance was poor and at one point she was away six weeks on a trip. When she returned she just couldn't settle down. By having the teaching assistant or the coordinator sit beside her and encourage her to trust her own judgment and work a little faster she began to make a score of over twenty correct responses in her Reading-for-Comprehension CAI lessons. Soon she was able to make between 90 and 100% with twenty-five or more problems attempted. By the end of May she had gained 1.4 years with a total of only 86 sessions. The average gain in the Reading-for-Comprehension curriculum in 4th grade was .9. Eva's success inspired her younger sister to improve her lessons also. Two happier little girls were proud of their CAI accomplishments by the end of school.

* * * *

Mike was a fourth grader assigned to the CAI reading curriculum. He reached 4.5 in the first 10 lessons with rapid motion but never got past 4.7 the remainder of the year. He would look at a question and find every reason not to read or answer it. He seldom answered more than 10 or 11 items in 10 minutes. At one point I had him start over. The first lesson he made 100% and then he went right back to his previous pattern of slow motion. This child was a behavior problem in his regular classroom and on the playground. His home consisted of a young father and his younger girl friend who appeared indifferent to Mike's progress or behavior in school.

* * * *

The most conspicuous failure in four years of CAI was Rajah. He was a fourth grader assigned to the CAI Reading curriculum. This child was capable of doing satisfactory work but could not accept the computer report of less than a perfect score. He complained that the computer cheated him as he pounded on the terminal or ran away. He was under the counter or screaming half the time he was in the lab.

The teaching assistant in the lab would sit beside him and try to keep him calm. Finally it was decided his disruptiveness was unfair to the rest of the class and he was dropped from the study. Many days he tried to sneak in and sign on for a lesson but he never gave up wanting a 100% lesson.

His problems in all phases of school life continued the entire year. The NPI at UCLA is trying to help this boy and his mother at the present time.

In School 2--a small school with less turnover than other schools in the study--the following successes and failures were reported:

Two 5th-grade students topped out of math this year. They are bright, eager, achieving students in every respect but what makes one story unique is that one of the students was asking for a transfer. There had been a spate of springtime name calling and this student had been targeted because she is markedly different, the only oriental in the school. Sympathetic support from her teacher, counseling by the principal, support by her peers had been to no avail. She still was determined to go to a school with "her own" as she put it. As educators we know that if she ran from the problem it would never really get solved. There was only one thing that had not been tried--with the help of her friends and her competitor in the C.A.I. lab--we told her that if she left, the remaining student would top out while her chance would be gone. It worked. She came back, faced the problem and topped out of math. She was the first student in four years of CAI to top out of the math curriculum. Her competitor topped out a few weeks later. We think of CAI as an academic remedial program but it does act as a challenge and motivator for high achievers as well.

* * * *

One student had been coming to the CAI lab on math for three years. To say he was bored is not to say enough. He was clever enough to time the problems so he would do the absolute minimum and get a percentage that would not move him too many points higher but still not incur the anger of the CAI coordinator. I thought for a long while that he really didn't like math and this was his way of getting by until his sibling was also enrolled on CAI. Her response was pretty identical to his. And then I met the parents at Open House and it became only too clear that these students were reflecting parental values, "machines aren't necessary". "When I went to school all we needed was a chalkboard." "Why spend our taxes this way," etc.

> It would have been a little more acceptable if they lived that way but even a casual inquiry revealed that they had the usual TV, washing machine, dishwasher, car, etc., all the electronic helpers of our age. School, however, was to stay unchanged. A 19th century approach to 20th century problems.
>
> Let me put it this way. We are rapidly approaching the 21st century and we must as parents, educators and concerned citizens meet the needs of our children. A literate child with good basic skills both in math and communication is going to be able to function and succeed at whatever career or careers that they choose. There is great merit in exposing our children to technological awareness in a manner that they view the machinery as a tool. The CAI program exposed children to computers. They are not awed--"stupid computer" is a comment often heard. They really look at the computer as an aide, just as they view all machinery. They learn the vocabulary rapidly "bits vs bytes," "computer down," "reload," etc. and they understand at least the concept. When a student apologized to Dr. Ragosta for taking so long to complete a task she said, "the mechanic did some repairs and we dropped a day's memory." She knew what she was saying. It is a valuable experience for students to be able to understand the present. How else are they going to build the future?

School 3 is a large Title I school designated as a racially isolated minority school. The population is predominantly Black with an increasing percentage of Mexican-Americans. The coordinator reported on a generally successful year:

> A group of ten 5th-grade boys and girls were especially successful in the CAI lab this year. They were all assigned to the CAI mathematics curriculum. I believe their success was related to three factors; three of the 5th-grade teachers liked teaching math and placed special emphasis on it; the children responded enthusiastically to running reports and competing against their individual progress, and finally, the children took pride in the challenge the curriculum offered.
>
> There were no outstanding failures at School 3 this year. The few children who did not succeed in CAI did not succeed in the classroom either. One 4th-grade boy, assigned language, sometimes refused to do his lesson and left the room without permission. His teacher reported he responded to frustration in the classroom in the same fashion.

School 4 is also a Title I school with a large Spanish-speaking population. The coordinator--new this year--used a reward system of issuing tickets for good performance at CAI. The tickets could be used for admission to the "Westworld Arcade"--the CAI lab supplied with computer games and kept open for an hour after school. The following successes and failures were reported from School 4.

> At School 4 one or two transitional Spanish-speaking students were able to bridge the language hurdle and master the vocabulary in the language curriculum well enough to complete lessons with a degree of success. This happened much to the amazement of the classroom teacher who was sure the students must be removed from language and placed into mathematics. In the classroom, these students were not reading at all. One or both of these students were able to read aloud the problems and select the correct answer most of the time--without frequent help from the teaching assistant.
>
> The CAI language curriculum patterns may have been learned by these students through repetition. Perhaps the fear of negative peer judgment (lack of approval) or teacher disapproval may have inhibited these students in the classroom. They may have "given up" performing in English in front of other people. The computer is non-verbal and much less threatening than the teacher or other students. Perhaps that accounts for the students' progress.
>
> * * * *
>
> Juan, 10 years old is a 5th-grade student--quiet, sensitive child who was formerly enrolled in a Special Day Class. He is currently seeing the Mainstream Resource Specialist for 45 minutes daily in addition to the corrective P.E. specialist weekly. This was his third year in the CAI lab.
>
> Juan began hanging around the lab, after the first of the year, at any free-time periods, recess, lunch and especially after school. Because he was assigned to the Reading and Language CAI curriculums and received 100% daily (a $1.00 ticket per perfect score), he was one of our earliest "steady" customers in the Westworld Arcade (Admission: $2.00 in ticket money). He carefully observed the activities and soon volunteered to lend a hand by teaching some of the computerized games. We found this a great assist as time was at a premium with 20-25 students in the lab daily during the 3:00-4:00 o'clock time slot. From this point he moved on to assisting with the clean-up after closing. Then he began collecting admissions.

He was very adept at the later, ironically in that he was doing poorly in math and was seeing the specialist for improvement. He was extremely careful in collecting the correct change, often to the duress of his peers who offered bribes and threats to gain entrance.

Near spring vacation Juan had become a regular CAI employee. He had so carefully observed our back-up procedures and security checks on closing that he finally asked to perform. He thrilled in assuming responsibility. Shortly afterward, he was meeting our cars on arrival, pacing back and forth along the fence if we were a little late. This was especially interesting when we found he lived farther from school than any other child in walking distance. He was officially in another school's attendance zone. His daily walk must have taken a good thirty minutes either way. Neither rain nor fog hindered his meeting us. He delighted in turning off the alarm, turning on the machines and setting the correct day and time. We noticed a steady improvement in his ability to state the correct time. He always made a point of checking that he was correct before typing the numerals. He delighted himself, as well as us, setting the military time in the afternoon back-up. Remember, Juan had been having extreme problems in math, but according to his classroom teacher and the Resource Specialist, has shown remarkable progress. He enjoys doing CAI mathematics demos and does only that at every opportunity. He could easily operate the lab, answering the telephone, keeping inventory, doing clean-ups, even doing minor typing jobs. He is usually the first to notice a problem in the machinery, often asking quite technical questions as to their function. It has been a personal joy and a professionally rewarding experience watching Juan progress through the months...thanks to CAI.

* * * *

James, 10 years old, is a fifth-grade student in a fifth/sixth grade combination class. He is a state-identified mentally gifted minor, a highly volatile boy who finds it most difficult adhering to school standards. He is the only child of a mixed (Japanese/black) union. He often feels he is being singled out for ridicule, when often he is guilty of the very same behavior by shouting inflammatory statements to his classmates in the lab. His group of eleven (11) students happens to be one of the smallest visiting the CAI lab. The majority of the class is Spanish-speaking, he being one of the two black males enrolled. His approach to the CAI was most inconsistent. He never arrived with his class, nor left with them. He was strictly a loner. He felt no compulsion to do make-up lessons nor to perform to his greatest ability. He was not challenged by motivational rewards. His overall progress though above grade level, was held to a minimum due to this negligent attitude. When this student was absent remarkable change was noticeable in his class's performance. He is currently seeing the Resource Specialist for academic assistance.

Even though the coordinators wrote about both successes and failures, they were able to think of many more successes than failures with computer-assisted instruction. Where CAI failures were identified, they tended to be associated with school failures in general rather than with CAI in particular. On the other hand, students who were not doing well in the classroom occasionally did quite well in the CAI lab and often reported liking CAI.

In general CAI coordinators perceived CAI as helpful to students and anticipated that CAI would become even more helpful when teachers and/or coordinators ran the program without the restrictions of the research design. The perceived success of the CAI program during its four years of operation laid the foundation for the successful transition of CAI from a federally-funded project to a school program. In an effort to help that transition and to perpetuate the knowledge and expertise gained by CAI coordinates, a conference was held at the close of the study, and coordinators helped to produce a booklet entitled Thoughts on a CAI Program. That booklet is included as Appendix B.

Student Perspectives

Each year of the study, students produced writing about CAI from assignments in their classrooms. During the last two years the stimulus for the writing was the following letter:

> Dear Student:
>
> It is not often that students in elementary school get a chance to influence decisions made by the government in Washington. However, you may be able to influence the government in two ways. You know you have been part of a federally-funded project about computer-assisted instruction. People in Washington will read the results of that research study and will make decisions about the future of CAI. They may decide to help other schools to get CAI or they may not. Before the government makes a decision, they should hear from you and your teachers. How do you feel about CAI?

With several hundred letters to select from, we have chosen 36 to report. The 36 are a selected sample of the more interesting letters. They are a biased sample in the sense that we have over-represented negative letters since they help to alert one to potential problems. In general, 65-70 percent of the statements about CAI made in any year by students were completely positive. Only 10-13 percent of statements made in any year were completely negative. The remaining statements were neutral or mixed.

The children speak for themselves without editorial assistance:

I think the computer is alright. And it does help you but I really dont like it that much. But I think I learn more from the computer. then I do from the techer.

* * * *

I think the computers are boring. You do the same thing everyday. I learn an awful lot. But I think it is boring. Espeacially when you don't understand something.

* * * *

At first I want to go to the Computer. And I still like the computer alittle but it helped me very much because at first I did'nt remember but the computer hlep remember more of what I'm doing and now I'm going in higher group.

* * * *

I think that the Computer is fun and it can help you learn, and to be smarter in class. A computer is a machine that give you all the answers. A terminal is something that gets it questions from the computer A computer is a nice thing to have. It helps you in what you need to work on. And a Computer is like a teacher. It asks you questions and you answer it. I think a computer is more smarter than you are and it is smarter than anything.

* * * *

I think the computor is allmost the best class in this whole school. For one reason it helps you to understand things that you dont understand and it helps you to know things that you don't know. You want to know. One more thing is I like the teacher. They are very nice if you don't know something all you have to do is raise your hand and they will help you. I am very happy that we have computor in our school. I wish that we would have got it earlier. I'm also glad that we get to go everyday of the week.

* * * *

I like Computer Lab, and then agian I don't.
I like Computer Lab for the idea of working with an important machine. And I don't like it because I want to work in math. I'm not very good in math and I would like to get better.

* * * *

The reason why I like the computer is because I learn new words everyday and I like, for instance like the word "capsize" it means overturn. And it strecthes my reading and makes it interesting and fun! So it really interest's me. And each day I go to the Computer I study the matter first and then type in my answer. Typing is part of the fun! I get familiar with which keys to punch in so I can finish my lessons, fast but carefully. And most of all it keeps me on schedule and on time for everything. Each terminal has a screen and it looks like a tv with a typewriter hooked on to it. The boringpart about the computer is the percentage like 100% and 95% or 80% or else 0%. Some of the times when I don't think about what I'm doing I accidentally push the credit button the computer counts it as a mistake. That's why I like the computer.

* * * *

I like the C.A.I. room because when I was little I got bored of the teacher talking. I wished that something could teach besides the teacher. Well I got my wish and I want to thank the people that let the boys and girls of (School 4) to go to C.A.I. room. Oh, and please let 3rd, 1st and 5th grades go to C.A.I. room because I feel sorry for them.

* * * *

I think the computer is something to look forward to. I know some people that like the computer as much as I. Sometimes I don't want to go because I am tired but I go anyway because I don't like class work. I like the computer work.

* * * *

I feel that the computer should have a button for when you want to use the restroom.

* * * *

I think the CAI stink. It is so boring. Sometimes I put the rite thing and it says rong. I think the CAI should be junked!

* * * *

Computers help me but I dont like them. They tire me out because the lessons are too long.

* * * *

I like the computers at our school. They help me to do my math. When I first came to class, I did not know to divide and when I started to go to computer I lerned how to divide. It helped me more with Multiplication, too. If little boys or girl's start when they are small they can learn better. We can do best if we start when we are like seven or less. Thank you.

* * * *

I don't feel that you should take computer out of school. For myself the computer has halped me a lot in my skills of language and reading. I have improved a lot. (and I got used to coming to computer) some people think computer is boring but it's not. So if you take the CAI computers my grades are going low. Sincely. PS. Don't take the computers.

* * * *

I like it because when I want to get in a higher level I just get in my right position and stop acting foolish I would just enjoy having a terminal at home.

* * * *

I like computer because we get time to get away from Mr. N.

* * * *

I think we should not have CAI because families would have to pay more money. I really don't like CAI because I think teacher's can teach more in a half hour than computors can and also they are uninteresting.

* * * *

Computers is an exiting event, everybody is working and trying hard to get one hundred percent. It feels like we're a great big family, just doing our jobs, so I like computers even though sometimes I get a low score.

From your computer lover.

* * * *

I think the C.A.I. program is fantastic. I think the program should be spread through out every school system in America.

P.S. Dont you think the computer should have spelling too.

* * * *

Listen up and listen good....I like these computers becouse they help you learn new things, they....help you in lots of ways. I have math and Im good at it but I wish I could be in topics or reading. Now I have lots of friends that likes computers and if you take them away we will be disapointed. So you better not take them away.

P.S. I fell sorry for you if you take them away.

* * * *

I feel happy in C.A.I. sometimes but I feel sad because I don't get 100%. I already have about twelve of them. I love to come to C.A.I. with my friends because we usually have fun. I am in one of the highest courses. I topped out of Reading and Language and now I am in Fractions. Everyday we go, you should see us how we run up those stairs. I really like it because the way the buttons sound when you press on them. I do my best and I love it.

* * * *

I would like the C.A.I. to be changed in a special way so that everybody could get a chance to go. I don't think it is fair. I would like the C.A.I. to be changed so that everyone could have a chance to work as a helper in the C.A.I. if they would like to. I would like to see the report on myself everyday. That's how I would like C.A.I. to be changed.

* * * *

I like computers and I don't like them. The reason why I like the computers is they helped me improve in my work and I became proud of myself. And the reason I don't like computers is because they force you to concentrate.

* * * *

I like computer. Sometimes I act hyper, in computer and sometimes I am mad and I don't do too good. Even when I'm happy I do terrible, but when I'm not happy or sad or made I do pretty well. I'm trying to tell you that my work in computer is how I feel. I try to do my best but, I have a habbit of showing off, I try not to but I can't stop, when I get in trouble in computer or anywher at school I get more in trouble when I get thome, by my dad. When people yell at me in school I don't think it's right, but after a while I understand.

* * * *

In computers my subject is Langage & Reading. I like doing the work except sometimes I'm not in the mood. but I know its helping me so I do the best I can. The lady that helps us Mrs. Lord is very nice she does charts of what were doing and makes schedules and she goes to other schools to help them. She puts all her efort in doing things to help us. Other kids don't really relize that. Any how I think you should go on with the computers because it helps kids more than they think and it teaches them how to be better at things that they have trouble on and helps them do the work faster and think faster. At my school they make games and all the classrooms try to get high scores in there work so that their class can win and get an award.

So I think that you should keep the computer program going even though they don't like it. It still make you learn & think faster.

* * * *

Computers sometimes are very boring, tiring and also no fun. But, then again, we run to C.I.A. after lunch 'cause the room is air conditioned.

* * * *

I dont think computers are very fun I know that I'm learning more than I would in my class aloan but I find CAI boring you keep on getting question after question I take only Math-M and would find CAI mor interesting if I could do some thing a little different once and a while. Truly, K. H.

* * * *

I thought the CAI was great because it helped me improve in math. I thought it was a challenge because I never get a 100% percent.

* * * *

I liked computers because it was a lot of fun. I had a lot of hard problems but I made it through those. When I had new problems I needed a lot of help, so I called on Miss V. I call her Miss V. for short. I thought it was fun because it was on a computer. You didn't have to write it on paper. I almost toped out at the end. My average was 78. Sometimes I got mad because I got a lot of problems wrong. I learned a lot in computers. The computer taught me a lot about math. I was lucky because math is my favorite subject. I liked my teacher Miss V. she was very nice. I am going to miss that computer room very much.

* * * *

To whom it may concern:

I thin you should leave the C.A.I. program running.

I had a lot of help from the computers in language and in reading. They teach you a better vocabulary than you already have. Because it sure improved my vocabulary alot better than it used to be.

So I think C.A.I. should proceed as it does now.

* * * *

How I feel about the C.A.I.

The C.A.I. is real boring but I guess it would be better if I had reading or language, but I'm stuck with math.

It also seems to waste time in my regular class & I've never gotten 100% in my course.

The teachers, Mrs. V. & Renee are very smart & its fun to talk with them. I think that even math is a good course for me because, I want to be a doctor or a Dentist and you need to know alot of math to do these things. (I'm not very good in math.)

* * * *

I like to do the computers becase I lern a lot.

I think that evre elemetry school shold have CAI what I mean is evere school in the world shold have CAI.

* * * *

I am proud of myself on the computers.

It is a neat experience to work on the computers.

I think I have gotten some good scores.

The computer teacher is nice and when ever I need help she's there.

* * * *

When I first started computer I really liked it. as I got older I didn't like it a as much. Now I'm in fifth grade and I dont like computer. It is a good program but It doesn't take my fancy. I don't like it because it gets me uptight and it makes me miserable. It makes me uptight and miserable because it is a computer, not a person, and computers are taking over the world! The End

* * * *

I liked the CAI room last year because I liked the work that I did there. It's fun because I don't have to write with a pencil. We could only type with are hand you can not write with a pencil and they help us learn the words like language or reading or math we learned a lot of things In the CAI room that's why I'm sorry we dont go to the CAI room any more and never again my my whole life. The end.

* * * *

1. I like the computer room because it's nice.
2. I might become a computer teacher some day.
3. The computers are nice to work on.

It must be emphasized again that the selection of student letters was intentionally biased toward negative comments in order to provide information about problem areas. A caution is in order, however. Most of the "boredom" responses were a direct result of the research design by which some students received nothing but mathematics CAI over periods of three or four years while their classmates received both reading and language CAI or a combination of all three CAI curriculums. In general, students enjoyed the CAI labs, behaved well and attended to task.

Teachers' Opinions

Each year teachers with CAI students were interviewed during the final week of school. This section summarizes the responses of these teachers in three areas: their evaluation of the CAI program, their ideas about how CAI is helpful to students, and their feelings about the transition of CAI from a federally-funded project to a school program.

Program Evaluations

In Chapter II it was mentioned that initial acceptance of the CAI program was less than whole-hearted due, at least in part, to start-up problems with the equipment and interruptions to the classroom organization in midyear. During years 2-4 of the study, teacher attitudes about CAI continued to be monitored. At the end of each year teachers of CAI students were interviewed and asked for their ratings on the following evaluative scales:

Overall, was the CAI program:

well run	1...2...3...4...5	chaotic
harmful to pupils	5...4...3...2...1	helpful
disruptive to class	5...4...3...2...1	non-disruptive to class
worthwhile	1...2...3...4...5	worthless
equipment undependable	5...4...3...2...1	equipment dependable
successful	1...2...3...4...5	unsuccessful

Are you glad or sorry to have had CAI in your school this year?

____ glad ____ sorry ____ mixed feelings

Mean ratings by teachers in years 2 through 4 on the program evaluation scales are given in Table 1. Data from year 4 are divided into 2 sections: data from Schools 1-3 and data from School 4. Since School 4 had a difficult year internally in 1980 and also had a new CAI coordinator, results from School 4 are perhaps less representative of CAI than of upheaval in the school. Having reported the data from School 4, we will not consider it further except to say, even here, the responses are more positive than negative. In general the ratings improve over time.

The positive evaluations in Schools 1-3 in the final year are in contrast with the previously reported results for year 1 of the study. At the end of the first year, there were serious reservations about CAI and the way it operated. Now, at the end of the study, it apears that these negative attitudes have largely been overcome, to produce what can be reasonably described as a vote of confidence from the teachers. All teachers in Schools 1-3 in the final year of the study reported being glad to have had CAI. (See Table 2.)

Scales regarding specific features of the CAI program give an indication of strengths and weaknesses. The most negative evaluations were of dependability of the equipment. Teachers occasionally reported breakdowns which caused disruption because of the necessary rescheduling and students' frustration. Some concern was expressed about disruption to class, although the large majority of teachers still rated the experience as nondisruptive. The program got very high marks for being well run, helpful, worthwhile, and successful.

Each year teachers were given a chance to make open-ended suggestions by explaining what they would plan if they controlled the program. Most

Table 1

Mean Ratings by Teachers in Years 2-4 on Program Evaluation Scales

	Year 2	Year 3	Year 4	
	(All Schools)	(All Schools)	(Schools 1-3)	(School 4)
Well run:	1.3	1.2	1.0	2.6
Helpful:	1.6	1.2	1.0	2.2
Non-disruptive:	1.5	1.7	1.5	2.5
Worthwhile:	1.6	1.3	1.0	2.6
Equipment dependable:	1.9	2.2	1.6	2.0
Successful	1.5	1.4	1.0	2.6

Table 2

Percentage of Teachers Reporting Being Glad or Sorry to have Had CAI in Years 2-4

	Year 2	Year 3	Year 4	
	(All Schools)	(All Schools)	(School 1-3)	(School 4)
Glad:	88%	91%	100%	58%
Mixed Feelings:	12%	9%	—	28%
Sorry:	—	—	—	14%

of the changes proposed had to do with the conditions of the experiment rather than with CAI itself. Most teachers appeared to understand the necessity of abiding by the experimental conditions but still chafed under the restraints. The most frequent suggestions were to assign students to programs according to need. The most frequent suggestion of this type was to use CAI for remediation when needed. Another frequent suggestion was to use CAI for enrichment and stimulation of more advanced students. Another frequently suggested change called for coordinating CAI lessons with the curriculum. A specific desire was the ability to use CAI for reinforcement--e.g., to give practice in a skill after a lesson in that skill. Several teachers mentioned changes in the scheduling. However there were no specific changes that were mentioned frequently enough to justify a recommendation regarding scheduling. Answers vary with teachers' styles and experience.

CAI Effects on Students

Teachers were asked to discuss examples of students who profited especially from CAI and students for whom it was a waste of time. Relatively few instances of waste of time were mentioned. The ones that were mentioned involved students who could not concentrate, did not cooperate, or had learning problems that made learning difficult in all settings. Few negative cases were cited. One negative result that sometimes occurred was the assignment of non-English speaking students to CAI programs in reading and language, causing increased frustration. This resulted from adherence to random assignment in the design of the experiment.

The teachers suggested a number of hypotheses about circumstances in which CAI might have especially beneficial effects. Two groups of students were mentioned repeatedly. The first was students who have limited English speaking ability. When assigned to CAI mathematics (as contrasted with reading and language), these students had a chance to go ahead with minimal frustration from language problems. The other frequently mentioned groups were above-average and gifted students, who get an opportunity to move ahead at their own pace. Several teachers reported being asked to explain concepts encountered in CAI but not covered in class. Often with a little bit of instruction from the teacher and coordinators, the student was able to progress.

A number of teachers mentioned motivational values, which especially helped some students. Here are some examples:

- CAI was credited in building self-confidence in a number of students. The feedback gives them confidence to try tasks they otherwise shy away from.
- Concrete knowledge of results encourages persistence.
- Awards and competition provide reinforcement that was highly motivating to students.
- The break from routine is motivating for some students.

Teachers often mentioned features of the process of CAI itself that are advantageous for some students. Among these were the following:

- The machine requires concentration and discipline. It provides structure. This is particularly useful for students who need training in self-discipline.
- The machine is benign. It does not require verbalization, putting ideas on paper or interacting with peers. Therefore CAI is an effective method for students who have problems in these areas.

There were a number of other ideas which were mentioned by only one or two teachers and which provide useful hypotheses.

- o Many students leave the area for weeks at a time and then return. CAI picks them up individually where they left off.
- o The computer does not "label" low achievers as do reading books and reading groups.
- o The short problems and immediate feedback are good for students with short attention spans.

The Future of the CAI Program

During the final year of field operations for the ETS-LAUSD Computer-Assisted Instruction Project, teachers were asked the following questions:

- .. If there were no coordinator next year would you feel comfortable bringing your class to the CAI lab on your own?
- .. Would you feel the need for in-service training on the computer? The terminals? The CAI curriculums?
- .. If you had your choice, how would you use (or not use) the CAI lab next year?
- .. What problems do you foresee for the use of CAI in future years?

Almost two-thirds of the teachers responded that they would be comfortable on their own in the CAI lab. Some expressed a preference for managing CAI themselves, although many more were concerned about the lack of a coordinator. Schools with small CAI labs--with 16 terminals instead of 32--were especially bothered by the lack of funds for a coordinator. "I don't know quite how it's going to work--bringing my whole class to the lab with only enough terminals for half. I'm not sure how to handle the children who can't be on the terminals. But we'll work it out." Only a few teachers were reluctant to be in the CAI lab on their own, and their perceptions were probably best expressed by the teacher who said, "No way! The technical problems would be terrifying." Only two of the 41 teachers balked at in-service training on the computer program: one because she felt she was completely nonmechanical and another because she was already overworked. Thirty-nine teachers responded positively to the need for in-service training. Many felt they knew a great deal already but could use additional help on the more technical aspects of the CAI operation.

Given their choice, 37 of the 41 teachers interviewed would elect to take their pupils to the CAI lab three to five times a week. One teacher would choose not to go to the lab and two others would send only selected students. One teacher had not made up her mind. Eight teachers would prefer to go to CAI only three days a week, while 29 would elect to go on a daily basis. Of those who specifically mentioned whether they would prefer to have one CAI session or two, more than 60% chose to have their students remain in the lab for two sessions of CAI. Mathematics was the CAI curriculum mentioned specifically most often, although many teachers mentioned selecting the CAI curriculum on the basis of need. (None of them recommended continuation of the process of random assignment of students to curriculums!)

The lack of money to run the CAI lab, the loss of a full-time coordinator, and the maintenance of the equipment topped the list of problems for CAI in making the transition from a federally-funded project to a school program. More than half of the teachers mentioned at least one of those problems. Staff training or in-service was mentioned as a problem by six teachers. Six teachers mentioned there would be no problem, and several mentioned computers as the tool of the future, receiving more and more use in the educational community. Lack of control in the CAI lab was reported as a possible problem by three teachers and scheduling by four others.

Despite the problems mentioned realistically by teachers, attitudes toward the future of CAI in the four schools were generally optimistic. Teachers knew that the transition would not be accomplished without problems, but they had little doubt of their own ability to cope.

The Principals' Perspective

The principal of each CAI school was interviewed at the end of the project, and all four were unreservedly enthusiastic about the success of the program through the first four years. In addition to the students' academic gains, the principals cited other valuable educational outcomes such as providing students with the experience of success and teaching them the discipline of staying at a task. The principals valued the fact that the program uses positive reinforcement and felt that the work was interesting and challenging for their students. Three of the principals made particular mention of the very positive attitude of parents toward the CAI program and credited the program with improving the relationship between the school and the community.

All principals expected to operate the CAI labs in their schools during the 1980-81 school year. What actually happened during that transition year is the topic of Chapter IV.

Summary

In Chapter III we have reported on evaluations of computer-assisted instruction from several perspectives. Coordinators of CAI labs wrote of their successes and failures. Students wrote of their pleasure and frustration. Teachers evaluated the CAI program, discussed its effects on students and contemplated its future. Attitudes of students and school personnel were overwhelmingly positive but problems were reported. Principals expressed concern about the transition of CAI from a federally funded project to a school program financed by the Los Angeles Unified School District. A report on that transition is the subject of Chapter IV.

Chapter IV

TRANSITION*

Of concern to teachers, coordinators and principals was the transition of the CAI program from a federally funded project to a program run by the schools. This chapter describes the transition during the final year of the project and the first year without project funding. There are two sections: a diary of the activities of the transition and a report on interviews with school personnel at the end of the year of transition.

The Diary of Transition

October, 1979

Planning for the transition from an externally sponsored project to a school district program administered by the individual schools began in October of 1979 with a meeting called by Dr. Warren Juhnke, Deputy Area Administrator of Area 4 and director of the project for the Los Angeles Unified School District. Present at that meeting were the principals and CAI coordinators of the four CAI schools; Ms. Roberta Woodson, coordinator for three years at School 4; Ms. Judy Newman, substitute coordinator at all four schools, interviewer, classroom observer, and testing coordinator; Dr. Marjorie Ragosta, ETS Project Director; and several Area 4 administrators, with responsibilities in the areas of learning disabilities, curriculum coordination, and general administration. Throughout the year of planning, this remained the core group, sometimes augmented by other specialists and administrators.

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*The major portion of this chapter was written by Puff Rice.

At this first meeting the two immediate responsibilities of each school were established--to develop an individual plan for a CAI program for 1980-81, and to begin at once to search for funding sources. None of the participants expressed the slightest doubt about wanting or needing CAI, nor did they express any hesitation about assuming full responsibility for running the program. The question of funding, however, especially in light of the scarcity of funds since the passage of Proposition 13, was seen as a serious problem. It was suggested that the Management Information Division of LAUSD might support the maintenance of the equipment and possibly even the rental of curriculums. Funds designated for instructional materials were also suggested as a source for curriculum rental money. It was felt that money for personnel to run the CAI labs would be the most difficult to obtain. Various possibilities were identified for exploration: Title I funds, bilingual education funds, Master Plan funds, ESEA funds (including funds designated for racially isolated minority schools--RIM), special federal or state allocations, Area 4's own money, a program plan with a budget submitted directly to the school board, and the "Adopt-a-School" program.

The attitude of the participants at this meeting was very positive, even while recognizing the reality of the funding problem. The group agreed to meet again in December to check on progress.

December, 1979

In addition to the core group, several Area 4 and district level administrators and consultants attended the December meeting, representing Master Plan, special education, curriculum services, learning disabilities, and the Management Information Division. Mrs. Eugenia Scott, Area 4 Superintendant, was unable to attend. Dr. Ragosta, who was also unable to attend, sent another member of the ETS project staff. The purpose of this meeting was to bring together and discuss the individual school plans.

Schools 1 and 2 had prepared a joint plan, since they shared one computer. Their plan called for serving the entire population of each school, including Special Day Classes. An adult ESL class would also be served at School 2. Because the CAI lab at each school was designed to accommodate only half a class, a coordinator would be needed at each school, so that children would never be left without a certificated teacher in charge. School 4's plan also called for serving the entire school, including Special Day Classes. Their plan suggested one coordinator to serve all four schools, with each school paying 25% of the coordinator's salary. School 3 also suggested a traveling coordinator but added the idea of one regular teacher at each school having responsibility for that school's CAI program. School 3 planned to involve all regular classes in the CAI program with the hope of expanding to include special education students and an adult education class.

On the subject of funding, Dr. Juhnke estimated a total cost for the four schools of $200,000. Schools 1 and 2 presented a joint budget of $89,033. They had no idea where that money might come from. School 3 submitted an optimum budget of $51,366 (with a full-time coordinator) and a marginal budget of $30,588 (with 25% of a coordinator). They expected to be able to support two teacher aides from their Title I funds but would need outside support for the rest. School 4, although they had not prepared a formal budget, estimated that they could provide two teacher aides from local school funds and 25% of a coordinator from their Title I funds. Even if the costs of hardware maintenance and curriculum rental were to be provided by the Management Information Division, as the administrators thought was reasonable to expect, funding for the bulk of the personnel costs was still a problem of immense proportions. All the schools firmly maintained that a coordinator was essential.

Facing the possibility of insufficient funding for the kinds of plans outlined by the four schools, participants in the meeting considered a number of other imaginative approaches. It was suggested that separate funds might be obtained for adult education programs, although such money probably could not be applied to the regular school program. The principal of School 3 indicated that he preferred "parent education," which is under the control of the local school, whereas "adult education" is not. He felt that a night program at School 3 would pose a serious security problem. A parent education program was also suggested for Schools 1 and 2, combined with a half-day program of CAI for the children at each school. It was felt that the local parents of School 1 either did not need or would not support such a program; the parents of children who are bussed from the other schools in the integration triad to which School 1 belonged lived too far away to participate.

A question was raised about the advisability of suggesting that the A-16 computers be "traded in" for A-17's, for which more varied curriculums are available. The consensus, especially among the core group, was that the schools needed to convince the school board that the equipment and the program they already had were good and should be maintained.

A proposal for Title IVc funding was suggested, but the administrators present felt that the CAI program could not qualify, since it would be considered an ongoing program rather than a new one. It was also pointed out that the competition for such money was fierce, and the grants were small.

Since School 1 and School 2 each had only enough terminals for half a class, it was suggested that the terminals all be housed in one school and the children be bussed from the other school. Although this would eliminate the necessity of having a certificated teacher in charge of each half of the class, the cost (in both time and money) and the administrative cumbersomeness of bussing more than outweighed the advantages.

One of the consultants suggested relocating the terminals in regular classrooms, two or three to a room, so that classroom teachers could use them like resource centers. This would completely eliminate the costs of coordinators and aides. It was felt that this would alter the nature of the program too drastically and would very likely result in greatly reduced benefit to children.

Summing up the meeting, Dr. Juhnke directed each CAI school to decide what program would be best for them, even if their program was different from everyone else's. He emphasized that "No Program" was not an option; although the funding agency had agreed to turn over the equipment to the schools at the end of the research project, it had done so with the understanding that the equipment would be used.

The attitude of grave concern for the future of the program that was expressed at the meeting was consonant with the feelings of the coordinators when they were interviewed several days prior to the meeting. They felt that no progress was being made in funding and that unless outside money were found the program could not function at all in 1980-81. Even the prospect of money from the Management Information Division for maintenance and curriculum rental did nothing to alleviate their fears. They all felt that the program would not be used without a coordinator. One coordinator reported that she had tried to train five primary teachers to handle a class in the lab. Four gave up after a short while; one continued to try but was ineffective. The coordinators were considerably more pessimistic than their principals and the Area 4 administrators about the fate of the CAI program in 1980-81.

January, 1980

A composite proposal for a CAI program for 1980-81, containing the final individual plans and budgets of the four schools was submitted to the Area 4 Superintendent by Dr. Juhnke in January of 1980.

The planned program for School 1 called for all pupils in grades 1-3 to receive CAI for 20 minutes each week. All fourth graders would receive 50 minutes of CAI each week. Individualized instruction would be provided for Special Day Classes, ESL children, and mainstreamed children. (There were no fifth or sixth grades at School 1 because of the integration triad arrangement.) The cost for the program at School 1 was $31,727.

School 2 proposed providing CAI for all students in grades 1-6 for a minimum of 50 minutes per week. Children in Special Day Classes and ESL children would receive individualized instruction. School 2 planned to continue to offer ESL parent education using CAI. The budget for School 2, including hardware and software costs for School 1, was $53,754. (School 1 used the computer housed in School 2.)

School 3 planned to provide CAI for all pupils in grades 1-6, with the amount of CAI time per week varying according to need. Individualized instruction would be provided for pupils with exceptional needs. A community adult education plan would also be offered. School 3 proposed a minimum budget of $29,340 and an optimum budget of $51,013.

School 4 proposed a CAI program for all pupils in grades 1-6, for varying amounts of time according to need. The minimum CAI time for any student would be ten minutes daily for one semester. School 4 also proposed individualized instruction for pupils with exceptional needs and a community adult education program in basic skills and ESL. A unique feature of School 4's plan was an enrichment program for state identified gifted students. School 4's budget was $29,449.

It should be noted that all of the final budgets were slightly lower than the original estimates discussed at the December meeting. The optimum total budget ($165,943) was $34,000 lower and the minimum total budget ($144,270) was $56,000 lower than the estimated total of $200,000. Possible sources of funds were suggested in the proposal, including Title I (for Schools 3 and 4), integration funds (for School 1), the Management Information Division (for hardware maintenance and curriculum rental), ESEA funds, Master Plan for Special Education funds, a grant from the Bureau of Education for the Handicapped, bilingual education money, state identified gift funds, and private industry.

The tone of the proposal was quite strong and positive, citing the record of success already established by CAI and the monetary value of the equipment soon to be transferred into the school district's possession. The proposal pointed out the strong foundation of trained staff and of community and teacher support that had been developed over the first three years of the project. The many ways in which CAI saved classroom teacher time while providing documented educational benefits to students were enumerated. The proposal closed by stating the willingness of all four schools to work with the Evaluation and Research Branch of LAUSD to build evaluation components into their programs.

May, 1980

At a meeting of CAI principals and coordinators in May, Dr. Juhnke summarized the progress of the composite CAI proposal since January. The proposal was submitted to the deputy superintendent of the district in January. The CAI principals, one of the coordinators, the Area 4 superintendent, and Dr. Juhnke met with him in February to discuss it. The deputy superintendent strongly supported the proposal and appointed a committee to investigate possible funding sources. That committee met in March. The results of its deliberations were negative: any Title I monies applied to CAI programs would have to be drawn from the local school's regular Title I budget; although schools that received School Improvement Program funds could elect to use those funds for CAI, no additional SIP funds would be forthcoming; there would be no involvement with adult education programs.

The only positive news about funding was that the Management Information Division had received a lower bid than anticipated for hardware maintenance and expected to be able to cover that expense as well as most if not all of the curriculum rental costs. By way of underscoring the severity of the school district's financial plight, participants in the meeting were informed that the district's expenditures had exceeded its income in 1979-80 by $20,000,000, and that $60,000,000 had been cut from 1980-81 program funds in the preliminary budget. Although he remained stubbornly optimistic, Dr. Juhnke realistically advised the coordinators to make alternate employment plans for themselves for the coming year.

The possibility of applying for a Bank of America grant was discussed. It was felt that individual schools stood a better chance of receiving such grants than would the four schools applying together. The grants would not be large enough to cover the cost of a coordinator, however. The Bureau of Education for the Handicapped was also considered, and preliminary investigation indicated that they would consider a small proposal for a study of the use of CAI for the handicapped, but such a proposal could not be funded by September. The individual schools were instructed to look at their proposals again, eliminating the hardware and software costs, and to see how close they could come to meeting the rest of the costs through their local budgets.

Dr. Juhnke reaffirmed his belief that the deputy superintendent was committed to the program and that LAUSD would not let the equipment sit idle and the coordinators' expertise go to waste. The Area 4 superintendent, who was able to come to the last part of the meeting, agreed that the financial picture was dismal but stated that she had faith that a way would be found. The coordinators were disappointed and downcast. The principals--particularly of Schools 3 and 4--continued to wrestle with the problem, searching for some way to carve out enough money to keep the program alive. It was generally acknowledged that without a coordinator the program simply could not serve as many children effectively as it had before.

June, 1980

The principal of each CAI school was interviewed at the end of the school year to discuss their plans for 1980-81. Looking ahead to the first year of operation as a school-run program the principals expressed several concerns that were common across all four schools. Foremost was the lack of funds for coordinators. At this point the principals had abandoned hope of any funds other than those to be provided by the Management Information Division. All the principals felt that the coordinator was the key factor in making the program run well, and they expressed keen regret that without a coordinator the program probably would not be able to serve all of the children that it had the potential to serve. Without a coordinator, individual teachers must learn much more about managing the program than they had to know before, and that meant inservice training, another problem of time and money.

A second common problem was the general uncertainty about school enrollments, which left such matters as class size, number of classes, assignment of faculty, and even budgets to be settled some time after school opened in the fall. Although this was an uncertainty which administrators always had to live with in Los Angeles, the situation was further complicated by the district-wide integration program that was in the process of being challenged and redesigned. School 1 and School 3 were each involved in cooperative integration plans with schools in other locations.

The Title I schools (3 and 4) had some similar features that influenced their plans for running their CAI programs in 1980-81. Both schools were large. Both had enough terminals in the CAI lab to accommodate an entire class, so that the regular classroom teacher could accompany students to the lab, and all students in the class could work on the terminals at the same time. The Title I budgets provided some funding flexibility that the non-Title I schools did not have. Two teacher aides for the CAI lab were written into the Title I budget for each school. At School 3 the same aides who worked in the lab in 1979-80 expected to return in 1980-81. School 3's Title I budget also included funds for a "professional expert" to spend some time training teachers to use the system. School 3 expected to hire as a "professional expert" their former CAI coordinator, who planned to take a year's leave in 1980-81. At School 4 the Title I budget included money for 25% of a coordinator, which was a possibility being considered at the time budgets were being prepared. Although the school district had abandoned that plan, the money was still in the budget, and School 4 had not yet decided how to make the best use of it.

School 3 had made definite plans for 1980-81, involving the groups that the principal felt had benefited most from the program in the past--the fifth grades (whose teachers were also the most enthusiastic about CAI), the Special Day Classes, and the children in the Master Plan program. Children would go to the lab every day for at least 10 minutes. Regular fifth graders would receive the math curriculum, SDC children would receive math and reading, and Master Plan children would be assigned to curriculums according to their needs. After one semester, more classes would be added to the schedule if possible.

At School 4 no definite plans had been worked out at the time of the interview. The principal expected to be able to formulate a plan during the meetings with resource teachers after the close of school. The principal anticipated that the responsibilities of part-time coordination could be assumed by one or more of those teachers. Although the principal of this school had been highly supportive of the CAI program from the beginning, and although the program had been regarded as successful by the participants in this school, the school and community turmoil of 1979-80 consumed all the energies of the principal and staff, and it was not possible for them to adequately address all of their other important concerns.

The two small non-Title I schools shared problems quite different from those of Schools 3 and 4. Schools 1 and 2 both had CAI labs with only enough terminals for half a class. The absence of a CAI coordinator meant that a teacher must take the entire class to the CAI lab, even though only half of the children could work at the terminals at one time. This had been tried with varying degrees of success. For 1980-81 it was suggested that some rearrangement of the terminals and counters in the lab might make this a more workable procedure. Another possibility was to have teachers work together, regrouping children so that those who needed extra work could go to the lab with one teacher while the others stayed in classrooms covered by other teachers.

An additional problem shared by Schools 1 and 2 was the lack of access to funds outside the regular school budget. The principal of School 1 thought that funds designated for a library aide might be used for a CAI aide instead. School 2's principal planned to hire a half-time aide using some carry-over funds from 1979-80. School 1 expected to have their former CAI coordinator back as a regular classroom teacher in 1980-81, but it was not at all clear how they would be able to make use of her expertise without sacrificing her classroom responsibilities, since there were no funds to cover additional hours for her as a coordinator or "professional expert."

Neither principal could specify at this point what their CAI program would look like in 1980-81. Those decisions had to wait until the fall. The principal of School 1 expected to use the lab for older children first, adding the younger ones if possible. Preference would be given to teachers who were enthusiastic about CAI, because the principal felt they would make the best use of it. The principal of

School 2 planned to use CAI for all classes, including the Special Day Classes and the adult ESL class that began using the lab in 1979-80.

Through all of the discussions of future use of the CAI program, the problem of not having a full-time, certified teacher as a coordinator was the common thread. Without a doubt the coordinator was viewed as the critical factor in a successful CAI program, but the principals were determined to find a way of getting some good out of the program in 1980-81.

October, 1980

Dr. Ragosta visited the four CAI schools in October, to learn at first hand how the CAI programs were progressing. The situation was worse than anyone could have anticipated--there were no programs to observe. The LAUSD budget had been cut by $80,000,000, and there was absolutely no money for CAI programs, not even for maintenance or curriculum rental. Moreover, neither of the Bank of America proposals had been funded.

The enormous budget cut was a major disruptive force in all the schools not only because of its effect on special programs but also because of its impact on class and faculty size. A related and equally powerful force was the desegregation plan, which drastically altered both the total enrollment and the grade makeup of many schools. Because the desegregation plan was being redesigned even as it emerged, it had the effect of keeping schools and communities in a perpetual state of uncertainty about what new arrangement might be imposed on them tomorrow.

At School 1, the desegregation triad that had seemed to work well for two years had been abandoned. School 1 was now sending its first, third, and fifth grade students to another school and receiving a proportionate number of second, fourth, and sixth grade students in exchange. (In past years School 1 kept its own students in grades K-3, received fourth graders from two other schools, and sent its fifth and sixth graders to the schools from which the fourth graders came.) The principal had no money to do anything with CAI and doubted that the program could operate at all in 1980-81.

At School 2 the situation was equally gloomy. The principal expected no resources of any kind to enable the school to run a CAI program.

The new principal at School 4 was interested in CAI as a means of lessening the "white flight" that was expected to result from the new desegregation arrangement in which School 4 was involved. No one was quite sure just what that arrangement was going to be, and a lot of conflicting information had been received. Funding for CAI, of course, had not materialzed.

The principal of School of 3 was still doggedly pursing funds that might enable them to operate the CAI lab in the second semester. The principal had submitted a proposal for $5,000 to add to $8,000 of Title I funds. The combination would provide almost enough money for maintenance and curriculum rental.

Los Angeles administrators were agreeable to Dr. Ragosta's idea of submitting a proposal to the Office of Special Education to do a study of CAI for special education pupils. The possibility of removing the equipment from Schools 1 and 2 and installing it in special education schools was considered. The consensus was that whatever stood the best chance of reactivating a CAI program should be pursued.

December, 1980

As expected, no CAI program existed at School 1 or School 2, because of a total lack of funds. The two schools were now being served by one principal (who had previously been the principal of School 2), the former principal of School 1 having been transferred to another part of the district. The closing of School 1 was again being considered. The principal had been advised by the Area 4 office that there was absolutely no hope of any money for CAI for either school.

The principal of School 3 had managed to secure $12,000 in discretionary Title I funds, which he supplemented with $1,611 of School 3's own Title I money to make up enough to get a limited CAI program into operation. Because School 3 qualifies as an Educationally Impacted School, the resource specialist who agreed to serve as coordinator of the program was eligible to receive an 11% salary increment for her additional duties. The former CAI coordinator at School 3 returned to give a two-day inservice program for teachers and the new coordinator. The program was set up to serve all the fifth graders, three Special Day Classes, and ten children in the Resource Program, a total of 154 children. Although regretful that such a small number of students were being served, the principal was understandably pleased to have any program at all, given the odds, and felt that it was running well.

School 4 received a similar allocation of Title I money in mid-December and began making arrangements for a program. The principal had also applied for a special education grant but thought there was only a slight chance that anything would be forthcoming. The desegregation plan had been put into effect by this time, so that School 4 contained first, third, and fifth grades, and the school with which School 4 was paired consisted of second, fourth, and sixth grades. The principal mentioned the possibility of a different arrangement for next year, in which School 4 would become a magnet school, CAI being part of the "magnet."

March, 1981

The CAI program at School 3 was running well, serving 142 children in regular and Special Day classes and about 25 in the Resource Program. The new coordinator was, in the principal's words, "the heart of the program."

The CAI program in School 4 began operation in February. There were a few equipment problems and some difficulty getting repairs, but by March everything was going well. Two half-day teacher aides had been hired, one of the school's regular resource specialists was serving as a coordinator, and the original CAI coordinator for School 4 came every other Friday to help in whatever way she could. (She was also available by telephone in emergencies.) All classes except one first grade were participating in the program, including the Special Day Classes. The teachers and students were enthusiastic.

The outlook for 1981-82 in both schools was grim. The school district budget was cut by an additional $15,000,000 over the previous year's cuts, and funding in many categories was likely to be completely eliminated. The court ruling outlawing bussing to achieve integration was to take effect on April 10, 1981, but with parental discretion; that is, parents could chose to have their children return to the neighborhood schools or leave them in the schools to which they were bussed. The last nine weeks of the school year were expected to be chaotic. What September of 1981 might bring was simply impossible to predict.

June, 1981

The teachers at Schools 3 and 4 were interviewed at the end of the school year. School 3 had used all three curriculums for the regular fifth grade classes, rotating curriculums on a weekly basis. The Special Day Classes tried some reading and language but used mainly mathematics. Each class went to the CAI lab four days a week, for 15 or 20 minute sessions. The teachers at School 3 were uniformly enthusiastic about the program, the SDC teacher especially so. Several teachers mentioned the advantage of being in the lab with their students, so they could see where children were having problems and provide follow-up in the classroom. They were surprised to find that the Spanish-speaking children were able to make progress in the language curriculum.

At School 4, only the mathematics curriculum was used, and every class (except the one that did not participate at all) went to the lab twice a week. Length of sessions varied from 15 to 30 minutes. Of the 13 teachers interviewed, only one expressed consistently negative feelings about the program. The other 12 were glad to have had the program in their school, felt their students had increased their math skills, and characterized the program as well-run, successful, and non-disruptive to the class. There were various opinions about scheduling, especially with regard to the ideal number of sessions per week and the choice between taking half a class to the lab (leaving the teacher to work with a smaller group in the classroom) and having the entire class go to the lab at one time. Most of the first grade teachers preferred the latter arrangement. Three teachers said they would have liked to have used fixed strands (concentrating on one skill at a time) instead of variable strands (a mixture of many skills), so that they could have coordinated CAI with the regular classroom work. Two teachers who had worked with CAI in previous years said they preferred having the whole class working on the same curriculum. One teacher mentioned that she had used performance in the CAI lab to confirm her own observation of children who should be tested as possibly gifted. The two SDC teachers in particular reported that their students were very enthusiastic about the program.

The funding outlook for 1981-82 was even worse than the previous year. Rising costs and additional budget cuts made it impossible even to imagine where money for a CAI program might be found.

Appendix A

Log: November 6, 1976 to March 30, 1977 (Excerpts)

Roberta Woodson
CAI Room Coordinator

LAUSD/C.A.I. Project Roberta Woodson

November 6, 1976 LOG

The terminal room is shaping up. It's very exciting. The counters are in. Painting is done--walls yellow and doors orange. The room is ready for hardware. Somehow never thought it would really happen.

As the terminal room is taking shape, students are showing interest. Some of the most disturbed kids are very excited about the computer coming. It's been fun to show them the process of a classroom being converted to handle terminals and a computer.

When the workmen are sawing or hammering, the noise disturbs some of the classrooms.

A few complaints.

November 23, 1976

The terminal room now has its mistress: Clarissa the computer. In a few days one terminal will be installed, and we can begin working.

Yesterday was the first CCC Hardware in-service at School 3. CCC personnel directed us through protected routines. It is very fulfilling to finally work on hardware tasks. Anxious to begin with students.

November 24, 1976

Computer repairman here today. I hope computer and terminal will soon work. Room is shaping up--kids come by and ask to see what's going on, they seem eager to start. Next Thursday will be the first run-through of the schedule. Teachers are interested too.

Will be ready to enroll as soon as ID#s arrive and terminal and computers are working.

My Teaching Assistants are excellent and full of enthusiasm for the project. I am very happy with both of them.

November 30, 1976

Terminal and computer are UP-finally! Have enrolled all classes but one. Terminal is doing fine--pretty logical. Computer printed out bad!? for no logical reason.

December 2, 1976

First day with children! All day--very interesting. Fourth- and sixth-graders had many questions:

What is ID#? Why? How does computer know things?

This was just a general introduction to the room: No terminals. They were surprised that air conditioning was needed for the computer.

One second-grade teacher very upset that the groups were randomly selected, because the grouping was in conflict with her math grouping. I felt bad, but there was nothing to do except be flexible. In terminal room, some groups arrived on time, others not. These problems will get ironed out.

I hope the 10-15 minute allotment for 1/2 of the second-grade classes will be enough time in the room.

December 8, 1976

Kids all day again worked on keyboards--which keys are unique, etc. Children always anxious to come to the computer terminal room.

One class of 4th-graders seems very unruly--they have some trouble walking in and out. They stand out as a group.

Students keep asking when the rest of the terminals will come.

Ten-minute time makes it impossible to do very much readiness work with those second-graders.

December 10, 1976

One teacher is still upset that pull-out is random for her second-graders. She does not complain directly to me, only to other teachers. I usually hear it 3rd-4th hand.

One other second-grade teacher was disturbed by the random selection. Understandably, because the random selection at Grade 2 really wreaks havoc with the teachers' groupings.

The other teachers seem very cooperative; they seem glad to be relieved of their students for a while. Strangely enough, not too many of them have shown ardent interest in the terminal.

Two teachers so far and the assistant principal have come into the room and actually wanted to see the terminal function.

The teachers are not as enthusiastic as the students are. I think this will change when their students become more involved.

January 3, 1977

First day after vacation. All 32 terminals lined up on their counters. Unfortunately, only 8 are functional. The man from Cincinnati Millicron is here working on the computer trying to fix the rest.

Strange to see 32 terminal CRT screens instead of 32 smiling faces.

Lots of students are asking when will they start. One girl asked "Do we come to the incubator room today?"

Many teachers asking when will it start? Suddenly realizing CAI will permanently be in their schedule. Another second-grade teacher upset that it will break up her time. "What will I do?"

Fourth- and Sixth-grade teachers take this all more in stride. One says that CAI does not take the place of Math. She suggests I remind all the other teachers of that.

Teachers seem a little uptight about scheduling.

Fourteen terminals working at end of day.

January 4, 1977

Still waiting for computer to be completely up; 16 terminals are not working--

Tomorrow man will arrive to fix Clarissa.... (I hope!)

Working with machines is sure different because you cannot depend on them. Only 12 terminals working at the end of the day.

Several people came by to see the installation.

The CAI coordinator from School 2 came over very frustrated--her computer is down and she wants action. Even more impatient than I--didn't think it was possible.

CAI start up--probably Fri.--1/7/77--hope so. Getting anxious. So are the children.

January 5, 1977

Took 2 groups of 2nd graders just to introduce them.

They did quite well. Some trouble with finding letters of their name and remembering to space between # and name. Very excited students--particularly when their last name appears on the screen. They said--"He knows me!" "How does he know my name?"

Only 14 terminals working this a.m.

11:00 a.m.--Cincinnati Millicron's "John" here to work on the computer. Also Ray from Hazeltine working on line printer.

The coordinator from School 1 is very low. Morale is hard to keep up when your system is down.

Having to postpone start-up time hasn't affected teachers, as yet. Hopeful we can start up in the next few days--I'm not sure, though.

January 7, 1977

Yesterday and today--introduced all 2nd-graders to the terminals. All in all went very well. Students very excited to see their last name on the screen. Spanish-speaking students were equally excited as the others. My very bilingual TA explained procedures to them also. They put in their numbers and names very well.

Start up is definitely on Monday for all grades. The 4th-6th grade students have had no introduction--we'll see how everyone does.

Students just walk in and stare--very excited.

Two more teachers were in today and are interested in seeing how the terminals work.

January 10, 1977

We started!!

Very rushed--problems with numbers and names--

Problems with < and >.

Trouble due to newness of working. Time will probably take care of lots of the problems.

The lessons are a full 10 and 20 minutes. That plus the newness of signing in caused our schedule to run late all day. As the students get used to it, they will function more quickly.

Students were excited.

A few, after working a very full 20 minutes, were very tired.

I have still not mastered learning about the terminals. If kids press certain buttons, terminals go off. I will continue to look into all those things.

We should have introduced students to the shift key before we started--especially for the greater than/lesser than symbols.

January 11, 1977

Much better today.

Almost correctly on schedule, and many people knew how to sign in accurately.

Still some problems.

Spanish speakers have lots of trouble signing in. Also cannot read the Reading or Language curriculums. They do much better in math curriculum.

Staff Meeting: Public. One second-grade teacher very upset. Feels that reorganization has so drastically affected her instructional program, she doesn't know what to do. She doesn't like students pulled out of her class randomly. She said it takes her hours to reorganize her program around the kids who leave for their computer lesson.

Today, with all terminals functional, I feel more aware of how to solve minor problems. Students feel more successful today. They're aware of their percentile scores. Four students received 100% today. I am beginning a 100% club. Students may join if they get ten 100% scores. Very pleased with second day. Hope the project continues to improve.

January 12, 1977

More noise.

Students very high. Second-graders still have some trouble with name and number. Particularly, Spanish speakers. Also classes must be on time up to the terminal room or it really gets the schedule off.

4th-6th graders did much better today. Most of them much more fluent in signing on and off.

Today, only two 100%ers. One girl has topped out of the language program already. Put her into math curriculum.

Students must be punctual in order for all to go smooth.

Also have to get our routines more functional, too.

Ray from Hazeltine is excellent. Calls in to see how everything is doing. Very good maintenance.

January 13, 1977

Today was very smooth--in every way--all students were punctual--more fluent in signing in. About six got 100s; kids more excited.

January 17, 1977

Went pretty well. Kids high.

Beginning to make a list of Spanish-speaking kids that need to switch their reading or language treatments to math.

More 100s than ever today--about 16 or 17--mostly 6th-graders. Some 6th-graders very frustrated and yelling at machine--some will not try to be accurate. Worked more on coming in and leaving the terminal room more quietly.

Tomorrow is TV filming--should be interesting.

Visitors today. Stayed 20 minutes. One said that I run this room with an iron hand. Two 4th- grade teachers said it really is nice when 1/2 class leaves for CAI. They say the computer program is going very well.

January 19, 1977

Today--computer stuck again--so lost some lessons (the 10:00 a.m. group). Yesterday same thing happened at 2:20 or so. We fixed it, but I did call CCC. Kids excited today. My back-up was working in CAI room today. Now she's trained, in case I'm not here.

January 20, 1977

Teachers of 4th-6th grade complain that their kids are leaving and entering rooms quite noisily. Need some escorting.

Most kids just buzzing along. Some seem distracted and have very short attention spans. There have been fewer 100s.

January 20, 1977 (continued)

Changed Spanish-speakers to math treatments.

Also top-outs were enrolled in math.

January 21, 1977

Second-graders beginning to independently put in second course very well. At 9:45--10:00 a.m. "Computer Errors" appeared on some terminals. I called CCC. Had to cancel classes for the day. Luckily we run back-ups daily. So we may only lose today's work--I hope.

Computer up in afternoon.

All is OK.

January 24, 1977

Spanish 4th-graders who had treatments switched to math are doing much better. Frustration level down. Scores over 90%.

Also started noting down facts for teachers. Makes schedule more hectic. But I'm enjoying getting more specific about student's needs. Also, I'm so glad the Spanish-speakers are less frustrated--getting 99% and seem happier. TV outfit is still promising to arrive but has not appeared yet.

Later today is the teacher in-service for C.A.I. I'm both scared and looking forward to it.

The TV people came. We'll be on the news possibly between 5-6 tonite. Computer went down in the middle of videotaping!

In-service pretty good--but computer errors just before we began. Very frustrating.

Millicron man coming tomorrow a.m. to check soft disc error. So awful--I had to cancel classes--I guess the machine's limitations are really getting to me. We lost the last two groups today.

January 26, 1977

Computer Down!

January 27, 1977

During in-service, some teachers felt that horizontal addition and subtraction were not good for students--does it deemphasize place value? Wanted that comment brought to ETS's attention.

Also felt language program didn't leave enough time with answers. They flash the answer on the screen too quickly--

Computer still down!

Having big conference at School 2. CCC, Hazeltine and Cincinnati Millicron--Please fix what's going on.

January 31, 1977

Conferenced w/all teachers

February 1, 1977

Down in a.m. Some classes in p.m.

February 2, 1977

Down again this a.m. Very frustrating. Serviceman comes and fixes the machine and within a few minutes it does not work again. I wish the machine could be fixed once and for all. Computer errors keep appearing and reappearing. When will it end?

School 2 is still down.

February 3, February 4, 1977

Up and running. Very smoothly. Started to record %'s every day for all 6th-graders and some 2nd-graders. Then charting their weekly average scores.

Kids are very motivated about their scores improving. I think it's good to keep score even though its only the 100%ers.

February 7, 1977

Down again--extremely frustrating.

February 19, 1977

Two 6th-graders have bad attitudes toward C.A.I. One has math--she keeps asking for another course. (R-L) She gets very discouraged--left in the middle of a lesson. Too bad! Also had trouble handling herself in a regular classroom.

Most 6th-graders are very attentive--also 4th-graders. Interested to see how they do tomorrow.

February 18, 1977

Note: Students in 4-6 better behaved during first session. By second session--a little more mumbling.

Today with the new 30-second timeout replacing the 60-second timeout, there was lots of math. Students very frustrated, especially 2nd-graders; it will take them awhile to get used to having less time to do their work.

Second-graders now have 7-minute sessions instead of 10. First day today. All of them were particularly affectionate today (lots of hugs and kisses). I wonder if this was related at all to shorter sessions--we'll see.

One 2nd-grader turns off/on line-button to off to avoid getting timed out. Smart--huh? Another 4th-grader figured out Control Z. Very strange. [Note: Control Z is a method used to stop a session before the time is up.] Both are very hyperactive and have behavior problems.

February 25, 1977

Rainy days--two in a row--seem to affect behavior in CAI room as well as the rest of the school. Last 2 days kids have been more anxious and talkative. Scores even went down a bit. Concentration level lower.

It's so nice now that CPU and terminals are working all the time--for 2 solid weeks.

This enables us to move into areas of helping students and teachers.

March 2, 1977

As all machines are working better, this frees me to be more motivating to the students--developed 100% club for R & L; 85% for M, since it's a little more difficult. Students seem more motivated by this move, and more want to come at 8:30 a.m. and put in make-ups or demos. Also, 6th-graders want to do demos after school in lessons they don't have regularly.

March 4, 1977

Two kids asked--how about being able to rub out in math? [Literally erasing the numbers.]

March 9, 1977

Parent conferences today--kids bringing their parents to the CAI room--very exciting because children are enthusiastic about what they are doing.

85% math is pushing more students into getting better scores--also now taking attendance daily--I will do awards for perfect attendance. So everyone can feel comfortable receiving something. Now I want to begin to turn my thoughts toward low achievers--

Kids consistently scoring under 70, what to do??

March 10, 1977

Program is in very good shape right now.

Make-ups every a.m. Kids very enthusiastic.

I find time to teach--all 3 of us spend time with contact (physical, like patting on the back), touching. It calms the students--they feel more like working. It's important to them to know people are available to them as well as the machines. I work with some kids after school, going over concepts they find hard to understand.

Feel time has come when I can be more personally involved with kids and where they're at--academically and "affectively"--I always thought the job would become boring after awhile. I saw a lot of coordinators sitting around in some of the other CAI installations I visited, but I doubt that I ever will. Students have too many questions--there's too much to teach them.

One teacher is presenting the only problem--she feels CAI interrupts her instructional time--so she has many times forgotten to send her group until late--she also maintains that all special programs scheduled her students at the worst possible time.

March 30, 1977

After Easter. Now twice a week for one hour I'm alone. Room takes on a different feel--I must be more the "custodian" of the 30 students during this time rather than the teacher. But not too bad--

We have had 2 days when subs relieved the teachers for short periods to visit the CAI room. It was good. Teachers got more motivated about the program. The CCC in-service helped some teachers too.

I wonder how the end-of-year testing will affect us.

Appendix B

Thoughts on a CAI Program:
CAI Coordinators Debriefing Conference
June 8-12, 1980

THOUGHTS ON A CAI PROGRAM:
CAI COORDINATORS DEBRIEFING CONFERENCE

June 8-12, 1980
Montecito, California

Marjorie Ragosta*

in consultation with CAI coordinators:

Mary King

Marjorie Lord

Judy Newman

Ann Vasilopoulos

Rayma Wells

Roberta Woodson

* The help of Teri Mondeaux, Puff Rice and Gina Wilson must also be acknowledged.

Educational Testing Service
Princeton, New Jersey

"It's a crime to have
the CAI lab in use
less than full time."

The Coordinators

PREFACE

The ETS-LAUSD CAI Project ceased operations in elementary schools in Los Angeles on June 30, 1980. For 4 years funding from the National Institute of Education, direction from Educational Testing Service, and the tremendous work of personnel in the Los Angeles Unified School District combined to operate a uniquely successful project. During the 1980-81 school year the LAUSD and, specifically, the 4 schools with CAI labs will try to carry on the program without the government funding which produced and supported the CAI labs. The loss of CAI funding will mean no full-time CAI coordinators in the schools; in fact, most of the CAI coordinators will have moved away from the CAI schools by the 1980-81 school year. With money and CAI personnel gone, schools will have to rely on their own staffs to organize and manage the CAI program.

It is not an impossible task. In interviews in June 1980, most teachers in CAI schools had positive feelings about bringing their classes to the CAI labs on their own--once they had received some in-service training on the computers and terminals. The perceived success of the CAI program during its four years of operation laid the foundation for the successful transition of CAI from a federally funded project to a school program. In an effort to help that transition and to perpetuate the knowledge and expertise gained by CAI coordinators, this report has been written. To the extent that it meets the needs of those of you who will function in the CAI labs in the coming years, thanks are due to those who in the last 4 years made CAI work: our CAI coordinators. They were a dedicated lot. They pass their information on to you with the hope that computer-assisted instruction will continue to help students.

Resource People

The following people have given their permission to be contacted for help if needed.

	Phone Number
Marjorie Lord (4 years at School 1)	(213) 392-1086
Judy Newman (4 years as substitute)	(213) 456-3727
Ann Vasilopoulos (4 years at School 2)	(213) 474-9869
Rayma Wells (3 years at School 3)	(213) 450-2343
Roberta Woodson (3 years at School 4)	(213) 559-8121
Marjorie Ragosta Educational Testing Service Princeton, N.J. 08541	(609) 734-5702

NOTE: Computer Curriculum Corporation provides people for in-service training as part of its contract.

The CCC Proctor's Manual contains information on hardware procedures and routine problems.

The Teacher Manuals from CCC provide information on the three CAI curriculums: Mathematics Strands, Reading, and Language Arts.

CURRICULUM SECTION

The CAI Curriculums

Full descriptions of the CAI curriculums in Mathematics Strands, Reading, and Language Arts are available as teachers' handbooks from Computer Curriculum Corporation in Palo Alto, California. Each of the curriculums is composed of several strands, i.e., sequences of related items such as vertical addition, horizontal addition, measurement, etc., in the Mathematics curriculum. The strands structure allows each student to move at his own pace independently in each strand of the curriculum. In the mathematics curriculum problems can be presented to students in a mixed drill--called variable strands--or in a fixed mode within one strand. In the language arts curriculum questions may be presented to students in two ways: variable strands (mixed drill) or topics (single topic drill). The variable strand approach--in mathematics, language arts, and reading--is automatic and requires only one initial enrollment. Fixed strands in the mathematics curriculum and topics in the language arts curriculum require simple procedures whenever a specific assignment is made or changed.

Coordinators were asked to rank the CAI curriculums and their alternative methods of use. They ranked six alternatives: the Mathematics curriculum as (1) variable strands, (2) fixed strands or (3) a combination; the Language Arts curriculum as (4) variable strands or (5) topics; and (6) the Reading curriculum. The curriculums were ranked from 1 (the best) to 6 (the least helpful). Results are given in Table 1.

Table 1

Curriculum Rankings

COORDINATOR (1)	(2)	(3)	(4)	(5)	(6)	CURRICULUM	AVERAGE RANK
1.5	1	1	1	3	2	mathematics (variable strands)	1.6
4	3	2	3	2	3	mathematics (fixed strands)	2.8
1.5	2	3	2	1	1	mathematics (fixed + variable)	1.8
5	5	5	4	5	5	language (variable strands)	4.8
3	4	4	5	4	4	language (topics)	4.0
6	6	6	6	6	6	reading	6.0

Among coordinators there was general agreement that the mathematics program was best, language was next, and the reading curriculum ranked last. Within the mathematics CAI curriculum, variable strands was preferred although the combination of variable and fixed strands received almost an equal rating. Within the language curriculum, topics was preferred over strands. Specific comments on each of the six methods of using CAI are presented on the next two pages.

The Mathematics CAI Curriculum

Mathematics variable strands. This is suitable for most students most of the time to keep interest and attention high. It requires no extra work on the part of teachers. Research has shown it to be effective.

Mathematics fixed strands. This is especially good for reinforcement after a specific skill is taught in class. It is helpful to students with specific weak areas, for SDC students, for students in primary level of success. Its specific weakness is that it requires less concentration and tends to be boring for continuous use.

Combination: mathematics fixed and variable. This was used very successfully at the second-grade level and was felt to be appropriate for all classrooms at all grade levels. A good description of how the combination of fixed and variable strands can be used is given in the CAI program for grade 1 on page 6.

The flexibility of the mathematics curriculum allows teachers to decide how it might best be used to satisfy the individual needs of the students in the classroom. There is no necessity to choose one program for the whole class; the computer can easily be made to adapt to the special needs of the individual members. However, it does require some work on the part of teachers to come up with programs best tailored to individual students.

The Language Arts CAI Curriculum

Language strands. This was the language curriculum used for the CAI study. It is useful for most students in grades 3-6, although its range is much more restricted than in the mathematics curriculum. Bright fifth- or sixth-grade students may top out of the program. Spanish-speaking students (NES-LES) may not be able to understand the program. Some transitional, limited-English-speaking students feel little threat in using the computer and can acquire the technique and vocabulary to work in this curriculum with surprising success.

Language topics. Almost all coordinators ranked topics higher than variable strands. It is useful in reinforcing skills taught in the classroom or for students who need drill in weak areas. It works very well when the teacher can coordinate it with classroom activities. It requires more time on the part of teachers to determine the specific topics to be used and to access them on the computer.

The Reading CAI Curriculum

Reading. Movement within the curriculum is slow and frustrates some students. Others enjoy it. It was ranked lowest by all of the coordinators, although the research seems to show that it helps to build vocabulary.

A CAI Program for Grade 1

For pupils in the elementary grades--especially grades 1 and 2--only the mathematics CAI curriculum is available. Therefore, suggestions for grade 1 need very little modification to be suitable for grades 2 and 3.

Readiness Activities

First graders need some readiness experience before starting their CAI program. Children need an introduction to the terminal keyboard and practice in signing on. Experience with demonstration lessons (DEMOs) is helpful. Until children become familiar with the process, it is useful to have a 3 x 5 card with the information needed for each child to sign on. This includes the child's ID number, first name, and the letter necessary to access either variable math strands (M) or fixed strands (F). Teachers and aides can assist small groups. Cross-age tutors, experienced with CAI, could be very helpful.

First graders will also need help with the (very limited) reading vocabulary required for the mathematics curriculum, including:

Number and name, please
Course
Type
How many A's

Ones
Tens
Count by 1's

Pennies
Nickles
Dimes

Vocabulary in the first column is encountered in the early lessons.

Children also need to know the CAI lab standards of behavior in order to get the maximum benefit from their CAI experience.

The CAI Schedule

Depending on the individual school situation, first-grade classes might be assigned to the CAI lab for either semester or both. One 10-minute session daily, coming before or after a natural break in the school day, was suggested by all coordinators.

In the absence of a full-time CAI coordinator, teachers would bring their classes to the CAI lab, provide help to the students in the lab, and leave the lab with their students. Help would be provided whenever possible by a teaching assistant assigned to the CAI lab. Additional help could be provided by the classes' own teaching assistants in Title 1 schools.

In the schools with small CAI labs only half of the class at a time will be able to work at the terminals. Suggestions were made to have two or three banks of terminals and one or two banks of counter space. Independent work requiring a minimum amount of direction, materials, or supervision was recommended for the group not at terminals. One coordinator (in a large lab) said:

> I would pull small groups of children off the terminals to teach to specific needs as indicated by the CAI printout, then follow up with fixed strands in the problem area.

A CAI Program for Grade 1 continues on the next two pages.

Curriculum Options

Coordinators were equally divided in their choice of variable or fixed strands for the students' initial entry into CAI. In actual practice in the CAI study, the variable strands approach was used in grade 1. Although all of the Coordinators had been initially apprehensive at the thought of first-grade pupils starting variable strand CAI within five weeks of entering school, the first graders adapted readily to the program. The single complaint was that some children were going too fast! One K-1 teacher reported, "In my 17 years of working with K-1 students, this is the first year we have finished the book. I'm sure it's because of the machines." The variable strands approach has been shown to be an effective program.

All Coordinators agreed that weekly CAI printouts be used as a guide in assigning students to fixed strands for individual progress, for extra help in weak areas, or for reinforcement of skills taught in the classroom. Two coordinators suggested fixed strands for the first semester followed by variable strands for the second. Others suggested fixed strands once or twice a week, with variable strands carrying the major responsibility for the CAI program.

One Coordinator wrote:

> I would prefer to have my first-grade class use the CAI lab just before lunch for daily 10-minute sessions of math. I would want them assigned to Math variable strands first. After the rapid motion of the first ten lessons I would study the report to determine which children needed to be placed in fixed strands and which fixed strands to assign. Using the child's average score, it is easy to see where, or if, he is in need of extra drill in a particular strand or strands. I would be likely to have the children work Monday, Wednesday, & Friday on variable strands and Tuesday & Thursday on fixed strands. A report every Friday will show whether the fixed strand needs to be changed. If the child shows no progress he needs special help from the teacher--if he has made rapid progress he is ready for a different strand. Record-keeping for each child is important in order to know which strands have been assigned and for how long.

Motivational Hints

Initially students are highly motivated to work and to get good scores in CAI. Later the work gets more routine, and a little planning is helpful in keeping up motivation. The following methods have been found useful:

- Awards. Commercial awards available in ditto masters were used for scores of 80% or 90% or better. Teacher-made awards were also used, some of which are included at the end of this report. At least once, a student-designed award was used.
- Contests. Contests were run with classrooms competing against one another. Points were earned for each student in the class who scored at a certain level or above. Some contest materials are also included at the back of this report.
- Line leaders. The boy and girl who got the highest number of correct answers were line leaders on the way back to the class.
- Applause. For the highest number correct--or the highest number attempted--students were occasionally applauded by the other students.
- Manipulatives. For students with difficulties in adding or subtracting, manipulatives are helpful. One-inch blocks are recommended because they don't get into the keys of the terminals.
- Record keeping. Keeping a score sheet to monitor one's own progress was motivating to many students. Stickers or stamps for high scorers helped.
- CAI reports. Some students really enjoyed pulling their own CAI reports from the computer.

A CAI Program for Grade 5

For students in the upper elementary grades all three of the CAI curriculums are available: mathematics, language arts, and reading. With little or no modification a program suitable for fifth-grade students would also be suitable for students in grades 4 and 6.

Readiness Activities

Experience with demonstration programs (DEMOs) is helpful to students. It is also useful to prepare 3 x 5 cards with the information needed by each student to sign on: the ID number, the student's first name, and the letter(s) necessary to access the CAI curriculums which have been selected.

The CAI Schedule

There was remarkable unanimity among Coordinators as to how they would use CAI if they were fifth-grade teachers with classes of 30 children. Everyone chose to take the entire class to the CAI lab for a twenty-minute session every day. One Coordinator suggested that three times a week would be worthwhile if that was all that was possible.

Two Coordinators mentioned the desirability of arranging the schedule so that the class went to the CAI room in connection with a natural break during the school day. One felt that it was important to avoid interrupting the long reading period in the morning.

One Coordinator said she would certainly schedule the CAI work at a time when her teacher aide could go with her, so that there would be three adults in the lab with the children (assuming that a TA were assigned to be in the CAI room regularly). Another person emphasized the importance of recruiting parent volunteers and/or student tutors.

Curriculum Options

All of the coordinators chose to use the mathematics and language CAI curriculums.

Most of the coordinators said they would use a combination of variable and fixed strands, with variable strands serving as the core of either the mathematics or language curriculum. Students would be assigned to fixed strands in math or language topics for some lesser amount of time, either for remedial work as needed or for reinforcing specific lessons taught in the regular classroom. One coordinator mentioned that she would use only two or three lessons on one language topic instead of the full 10 that are available.

One coordinator indicated an interest in using the reading curriculum in combination with language, so that her students' time would be evenly divided between math and "verbal" CAI activities.

Several coordinators said they would have students run their own reports once a week and determine their own areas of greatest need. Then each child could select a fixed lesson in that area for extra drill. One coordinator said she would allow students to choose extra work in either the child's strongest or weakest area, so that students would have the opportunity of moving further ahead in the areas in which they excel.

Motivational Hints

Rewarding students for a high percent correct is probably a less effective method than rewarding for the number of correct answers. Most of the motivational hints listed earlier on page 9 are appropriate for students in upper elementary grades. Some examples of teacher-made awards are included in the back of this report. Also included is an equivalence chart which is helpful to students for use in the mathematics measurement strand.

CAI OPERATIONS SECTION

CAI: Job Description

The following tasks represent some of the responsibilities borne by CAI Coordinators (and ETS) over the last four years. This work must now be shared by many individuals. Administrative responsibility for these tasks should be established as quickly as possible, since much of the work must be accomplished in the first month of school.

First Month Activities before CAI Lab is Operational

- Getting the CAI lab up and running, including hardware maintenance and software preparedness.
- Hiring TAs; getting extra help, if needed.
- Scheduling/developing in-service training sessions.
- Developing the CAI schedule; promoting the CAI program.
- Working with teachers to develop student programs by selecting CAI curriculums.
- Entering and enrolling students in the selected CAI courses.
- Preparing students for CAI start-up: readiness activities.

Daily Operations in the CAI Lab

- Opening room, setting up equipment.
- Cleaning terminals and maintaining room environment.
- Monitoring CAI schedule; reporting problems.
- Assisting students at the terminals.
- Handling equipment problems.
- Providing motivational support/aids.
- Running weekly reports.
- Monitoring student progress on a regular basis.
- Enrolling students in specific fixed-strands or topics.
- Maintaining records/files.
- Running a back-up; turning off terminals.
- Closing the CAI lab.

Coordinators' Best Advice

Coordinators were asked to write down the four or five best pieces of advice they could give to people working in the CAI lab. Their answers were surprisingly consistent. They have been combined to produce the following advice:

- Have a very organized schedule and stick to it. Make no drastic changes. Plan your schedule carefully. Once the schedule is set, be firm. Remember time-on-task is important. (See Section on Scheduling.)

- Keep a positive attitude about CAI and continually convey it to students and staff in the lab. Show interest and encouragement. Show concern for student progress and maturity. Be positive and enthusiastic. Remember the job is routine--keep your own enthusiasm up. Smile a lot. Keep the CAI room cheerful and seasonal.

- Establish and follow through on good, fair standards of behavior so that no large problems arise. Maintain lab standards firmly. Establish orderly traffic patterns. Try to monitor what students bring in--food, candy, gum, sunflower seeds! Offer to save it until after CAI. Remind students, "We take care of the equipment." Keep pupils on task and out of trouble; urge them to work as many problems as possible.

- Have a lot of good, interesting motivational aids to keep the program alive and the students doing well. Provide tangible goals for students to work toward, and reward their progress. Give positive verbal feedback frequently. Develop some reward system for good lessons. Reward students who get a high number of correct answers rather than a high percentage of correct answers. Motivate with pats on the back, games, small prizes. (See samples of motivational aids at the back of this report.)

- Keep good, open communication among all participants in the CAI lab. Teachers, Teaching Assistants, and Coordinators are working together for the good of the students. Be cooperative. The success of CAI is related to the importance teachers place on it. Train TAs carefully. Give teachers as much choice as possible in scheduling and course assignment.

- Remember the hardware tasks. Simple back-ups and clean-ups help prevent larger problems. Don't worry about the hardware tasks. Relax. The equipment is fairly sturdy, and the damage you can do is minimal. It will not take long to learn.

Potential Problems with CAI

Coordinators were asked what problems they foresaw with running a CAI lab without a full-time CAI Coordinator and how schools could best cope with those problems.

- Maintenance of the equipment: Teachers are intimidated by machines. Many more people will be responsible. The phone lines between School 1 and School 2 have been a problem for two years; someone needs to be present in the School 2 CAI lab to handle that end of computer problems for School 1.

  Solution: Fantastic, dedicated TAs at Schools 1 and 2 could be trained to handle equipment problems. Overall, intensive in-service training for both teachers and TAs is critical. All teachers should be in-serviced adequately. All TAs in the schools should receive training. Time will help as teachers begin to feel more comfortable. Student helpers might also be trained for some tasks. A chart, explaining the most common equipment breakdowns and simple solutions, should be placed near the computer along with the phone numbers of service repairmen.

- Maintenance of the CAI lab: The room environment may not be kept up. Bulletin boards may not be changed and visual aids (e.g., equivalency charts) may not be provided. The terminals may not be cleaned. Motivational aids could be provided by each classroom teacher but, given the human factor, these may be less than optimally successful.

  Solution: Delineate responsibilities. Make sure each person knows what her/his responsibility is. TAs could carry most of this responsibility--cleaning terminals, providing motivational aids, maintaining bulletin boards--especially if they used student helpers before and/or after school.

- The optimal use of CAI: The CAI lab may not be used to best advantage. Teachers may find it more convenient to skip their class time in CAI. The CAI lab may not function for a full day; less than the full day would be a crime. In small schools with half the class working at terminals and half doing some other assignment, teachers will be hard-put to give help where help is needed. No one will feel responsible for the total program. Who will diagnose CAI reports and prescribe assignments?

  Solution: Cooperation among faculty, students, volunteers, and those specifically responsible for the CAI lab will help. Delineate responsibilities. TAs could be responsible for monitoring the CAI schedule. CAI reports and their interpretation could be the joint responsibility of TAs and teachers. Teach students to run their own individual reports, diagnose their own needs, and even assign themselves to work in fixed strands--if possible. Volunteers might keep the lab open at times when regular personnel are not available--before or after school.

- Record keeping: Who will be responsible for keeping files? How will student progress be monitored? Where will records be kept?

  Solution: Prepare file folders for the CAI lab. Keep copies of CAI reports in each class file. Reports at the end of rapid-motion are very important to help monitor student progress during the year. Assign this responsibility and establish the routine.

Example of Posted Directions

Directions for Substitute in CAI lab -

1. Check to see that alarm light (by door) shows "OFF".
2. Turn on air conditioner (small, flat, two pronged key-box on north wall by breaker box).
3. Turn on terminals (switch on back, lower left). Light will show in 30 seconds. Press CR key to get message: "Number and name please."
4. Check schedule--pass out report sheets for first class--place on counter to left of terminal.
5. Pass out report sheets for next class before first class leaves. No assigned seats--alternate boys and girls.
6. Take roll for each class--attendance sheets are on clip board in file box on first counter.
7. Primary recess duty on Thursdays and Fridays 10:30 to 10:30--check with TA.
8. Lunch time 12:15-1:00. Leave keys in office for TA. TA will wipe screens.
9. After school TA does "Back up" on computer. If TA is absent see Proctor's Manual for directions. (Top drawer of filing cabinet.)
10. Reports must be run for teachers every Friday. See manual and TA.
11. All terminals must have screens wiped with special cloth wipers stored under sink.
12. Turn off all terminals.
13. Dust keyboards with paint brush.
14. Put chairs up on counters, close blinds, turn off air conditioner.
15. Call security (625-6631) and tell them you are going to turn on alarm [.] Use key marked S-172 to activate alarm. You may not go back in lab again once alarm is on unless you call Security from office first.
16. Return keys to box in teachers' supply room.

Student Problems in CAI

There are probably fewer problems with students in the CAI lab than in most other areas in school. The work incentive is high. Nevertheless, some problems exist. CAI coordinators were asked what kinds of problems they looked for and how they solved them. Some of those problems associated with CAI lessons were:

- a student's pressing the wrong keys
  - caps only -- to produce all capital letters
  - control Z — to end the lesson
  - top left-hand keys -- to go off-line
- a student's inattention to CAI lesson
  - darkening the writing on the CAI screen so that it can no longer be seen
  - letting questions run by without answering
  - pressing the space bar without making an effort to do the work
- a student's frustration
- a student's interference with another's work

Speaking with children individually usually helps. Careful seating arrangements can solve some problems. Giving extra help to students when it is needed is helpful. Reminding children it is okay to make mistakes helps to solve some frustration problems. One-on-one contact with the teacher or TA often helps. When one child causes another to miss a problem by typing on the keyboard, subtracting points from the offender's score may help. More serious problems may be handled by a phone call or note to the parents, or by having a child come to the CAI lab with a different class.

SCHEDULING

Scheduling CAI

Coordinators were asked a series of general questions about how they would schedule CAI in an imaginary school: Bursting Place. On the next four pages are listed those questions and the coordinators' responses.

Assume you are principal of Bursting Place Elementary School, and answer the following questions:

How would you assign CAI?

Which classes or grade levels?

How long a lab session?

How many times a week?

Which CAI curriculums?

Bursting Place School: Hours 9-3
840 students 32 CAI Terminals

Grade	Classes	Class Names
K	6	1, 2, 3, 4, 5, 6
1	5	A, B, C, D, E,
2	4	F, G, H, I,
3	4	J, K, L, M,
4	4	N, O, P, Q,
5	3	R, S, T,
6	3	U, V, W,
SDC	3	7, 8, 9

Independently, every coordinator found a way to give CAI to every student at Bursting Place School! Coordinators were so convinced CAI is a worthwhile activity that they could not bear to omit any pupils. Most coordinators planned the schedule to give half the classes CAI in the first semester and the rest of the classes CAI in the second semester. In general, all coordinators felt there should be one 10-minute session in mathematics for pupils in grades 1-3 and two 10-minute sessions in mathematics, language, and possibly reading for pupils in grades 4-6. They based their rationale for one or two sessions on attention span. Many coordinators felt that students should go to the lab on a daily basis so there is a regular routine for CAI drill and practice. An alternate schedule would plan for pupils to go to the CAI lab two or three times a week. The coordinator who planned the schedule below said:

> The reason for emphasis on Grades 4, 5, and 6 (they receive CAI both semesters) is that the computer mainly helps individualize drill and practice. By grade 4, the range of levels in all academic areas is great and the classroom teacher needs more help to individualize the student's academic program.

Semester 1: Grades 1, 2, 4, 5, 6, + 2 SDC Classes

	Mon	Tue	Wed	Thur	Fri
9:10 - 9:20 Class	A	B	A	B	A
9:25 - 9:35	C	D	C	D	C
9:40 - 9:50	E	F	E	F	E
Recess Break					
10:20 - 10:30	G	H	G	H	G
10:35 - 10:45	I		I		I
11:00 - 11:20	7	8	7	8	7
11:20 - 11:40	N	O	N	O	N
11:45 - 12:05	P	Q	P	Q	P
Lunch Break					
1:00 - 1:20	R	S	R	S	R
1:25 - 1:45	T	U	T	U	T
1:50 - 2:10	V	W	V	W	V
2:15 - 2:35 MAKE-UPS					

Semester 2: Grades K, 3,4, 5, 6, + 1 SDC Class

	Mon	Tue	Wed	Thur	Fri
9:10 - 9:20 Class	1	2	1	2	1
9:25 - 9:35	3	4	3	4	3
9:40 - 9:50	5	6	5	6	5
Recess Break					
10:20 - 10:30	J	K	J	K	J
10:35 - 10:45	L	M	L	M	L
10:55 - 11:15	8	8	8	8	8
11:20 - 11:40	O	N	O	N	O
11:45 - 12:05	Q	P	Q	P	Q
Lunch Break					
1:00- 1:20	S	R	S	R	S
1:25 - 1:45	U	T	U	T	U
1:50 - 2:10	W	V	W	V	W
2:15 - 2:35 MAKE-UPS					

Several of the teachers who were selected to participate in the CAI program do not wish their classes to go to the CAI lab. How would you handle this situation?

The responses, when tabulated, indicated two solutions had equal weight with coordinators and could be used in conjunction with one another. One response stressed the importance of positive administrative attitude and support for all teachers to use the computer. The second response was to involve the teacher by demonstrating the positive uses of the CAI program for record keeping, meeting individual needs, and using reports for aiding students. Administrative policy combined with friendly persuasion could be used to encourage cooperation. There was no suggestion that the teacher or her/his class be excused from CAI.

Bursting Place School tends to track its students. Classes may be slow, average, or accelerated. Should any changes in the schedule be made in light of this information?

All coordinators agreed that all students--including accelerated and slow students--should be given CAI, with the emphasis on the math curriculum. The faster students could be given variable math and possibly language or reading, while the slower students could be given math, fixed or variable, and perhaps no language or reading curriculum. Several coordinators made mention of the accelerated learning and challenge that math presents to the higher achievers. However, if time and space were very limited, some coordinators felt that priority could be given to the slower students.

Bursting Place School has been identified as a low-scoring school in state-wide assessment. The school has developed a long-range plan for upgrading student achievement. How could CAI best be used as part of this 3-year plan?

Most coordinators did not change their earlier schedules on the basis of this new information. One coordinator did. She felt that by working with students in grades 1-4 the first year, 1-5 the second year, and 1-6 the third year, optimal results in test scores would be obtained in year 3. Her plan was to use variable strands of math (and language where it was appropriate) to identify weak areas for individual students. Fixed strands for mathematics (and topics for language) could be used once or twice a week for extra drill in weak areas. Cross-age tutors could also be provided as a program involving mentally-gifted minors at higher grade levels. Before-school and after-school programs on the computer could be run by parent volunteers. Such a long-range plan for the CAI lab should help to improve student achievement (and test scores) by the end of three years.

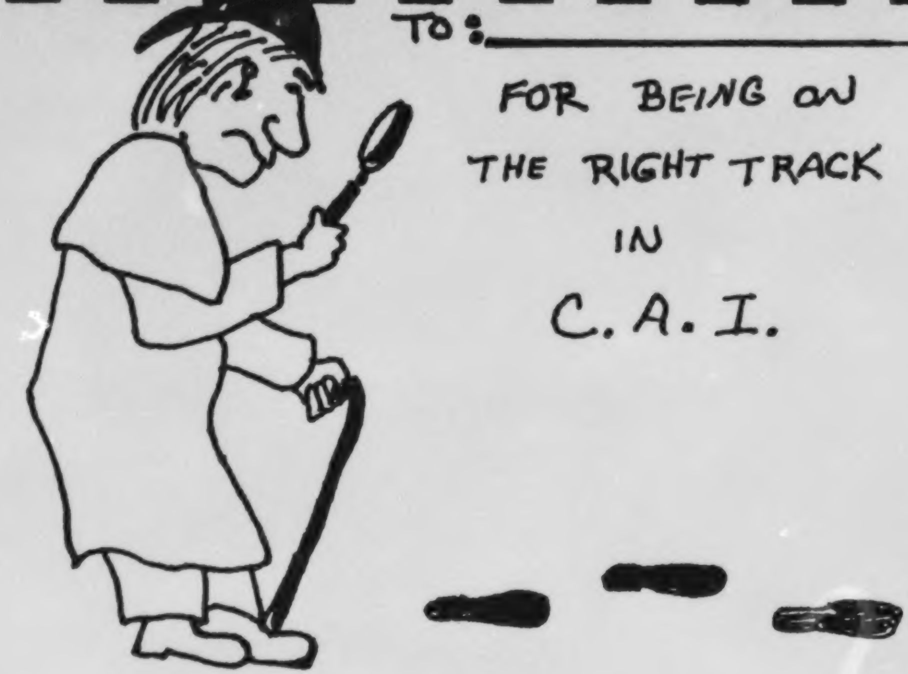
If a proposed new school were built, it would draw students away from Bursting Place School. It would be left with about 450 students. What CAI changes would you make?

Coordinators almost unanimously agreed that all pupils in grades 1-3 should go to the CAI lab for 10 minutes daily throughout the school year for the mathematics CAI curriculum; and all students in grades 4-6 should go daily, for 20 minutes, for mathematics CAI and any other curriculums the teachers may recommend as needed by the individual. This situation was perceived as ideal--when all students could have CAI on a routine basis all year.

VISUAL AND MOTIVATIONAL AIDS

TO: ____________________

FOR BEING ON
THE RIGHT TRACK
IN
C. A. I.



____

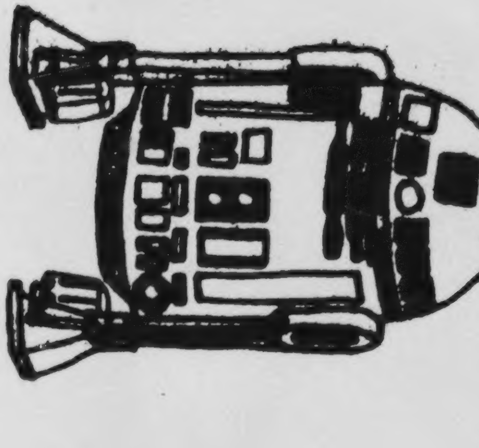
HAD A WHALE OF
A GOOD WEEK
IN
C.A.I.

____

IS REALLY PILING UP
SOME GOOD
SCORES
IN C.A.I.

...I'M...A...WINNER...IN...THE...

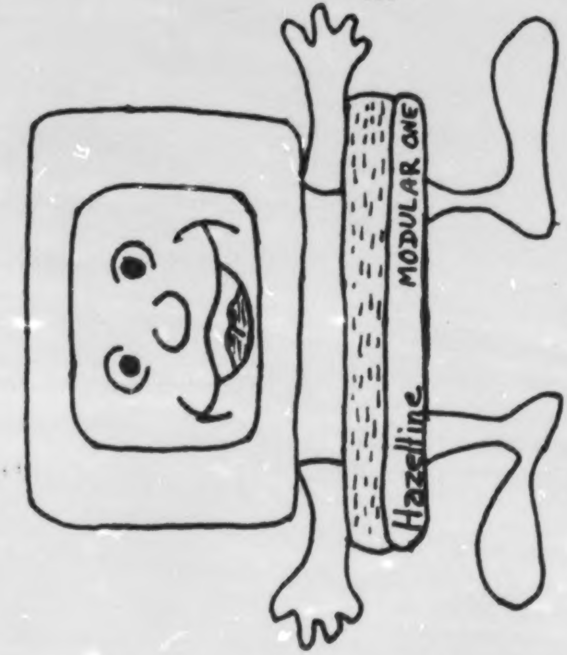
SCORE WARS



I EARNED A ____ SCORE IN C.A.I.!

COMPUTERS ARE

SUPER


Hazeltine
MODULAR ONE

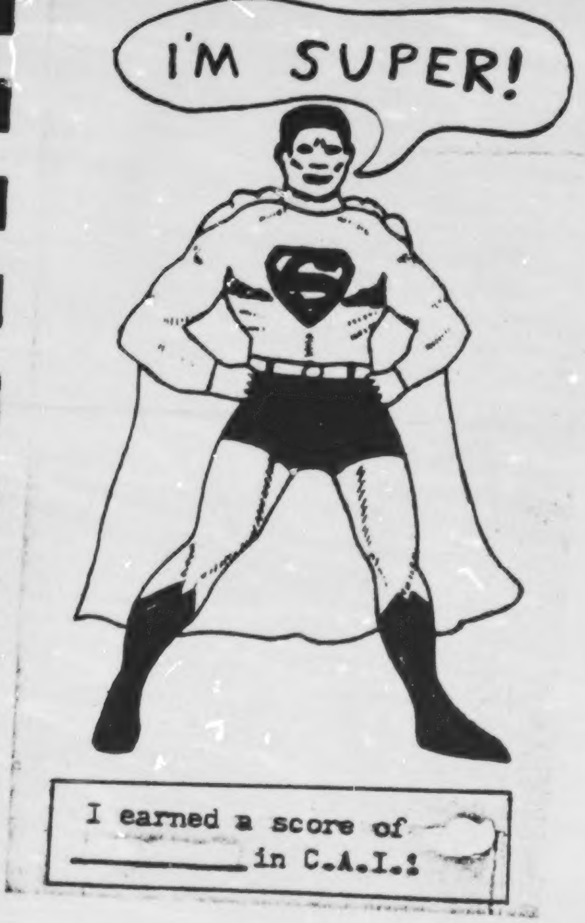
AND SO IS

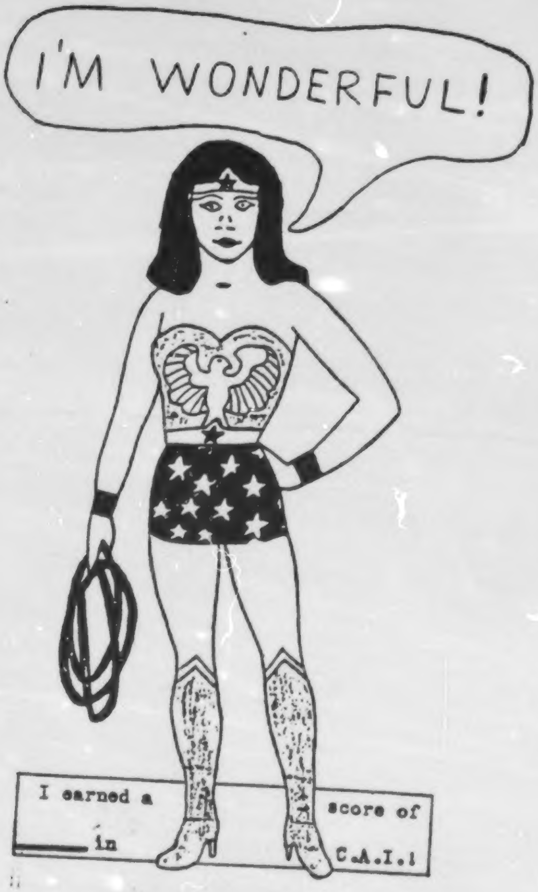
____

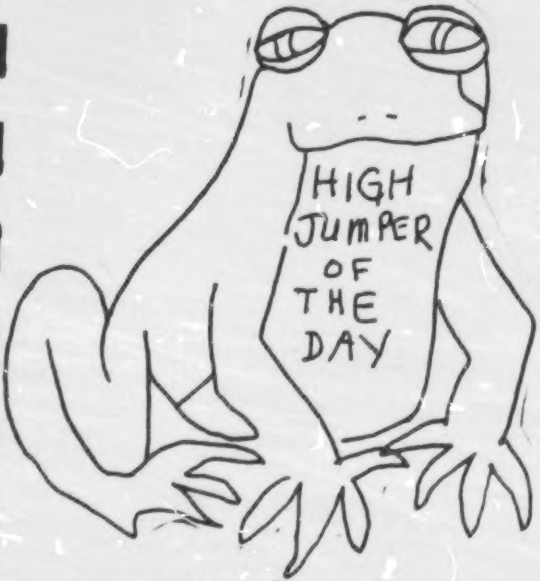
CONGRATULATIONS!

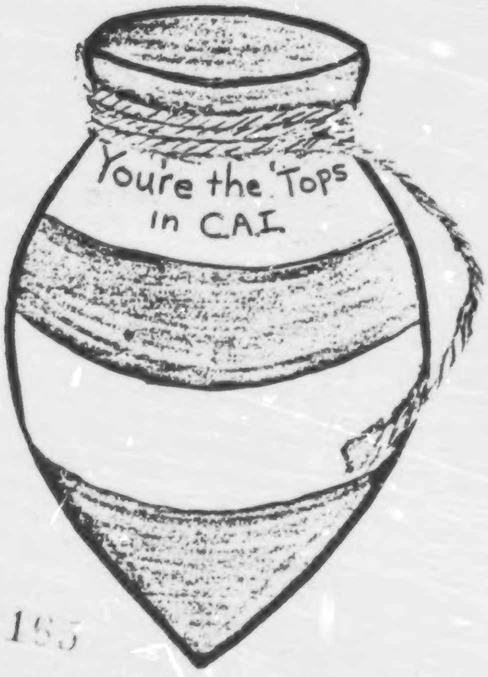
____

YOU'RE A SHARK
IN C.A.I.


I'M SUPER!
I earned a score of
________ in C.A.I.!


I'M WONDERFUL!
I earned a
score of
_____ in
C.A.I.!

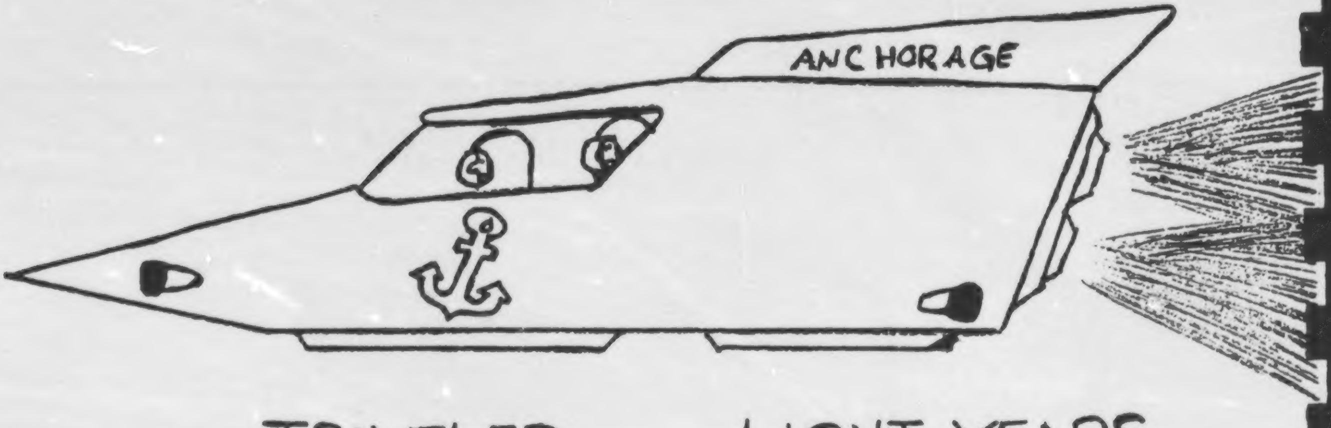

HIGH
JUMPER
OF
THE
DAY


You're the Tops
in C.A.I.

C.A.I. SPACE RACE WINNERS

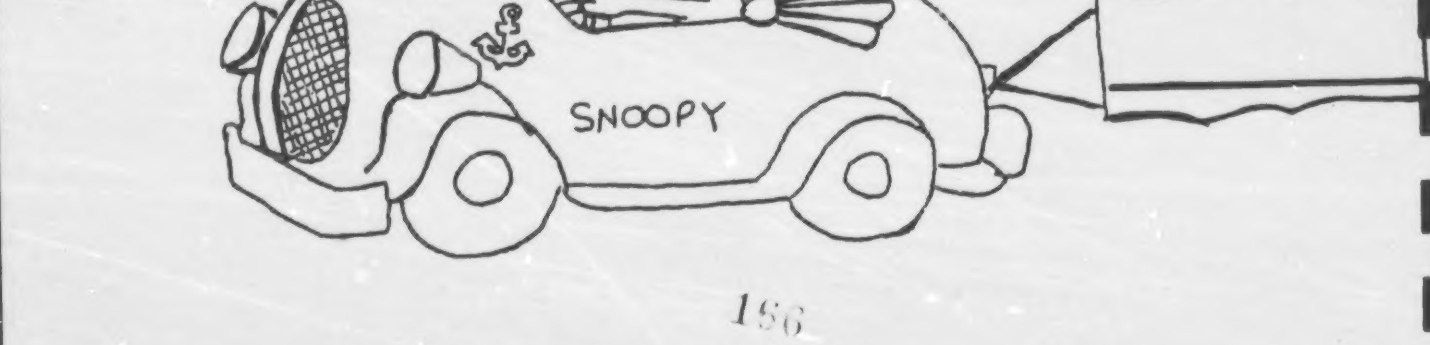
ROOM ___

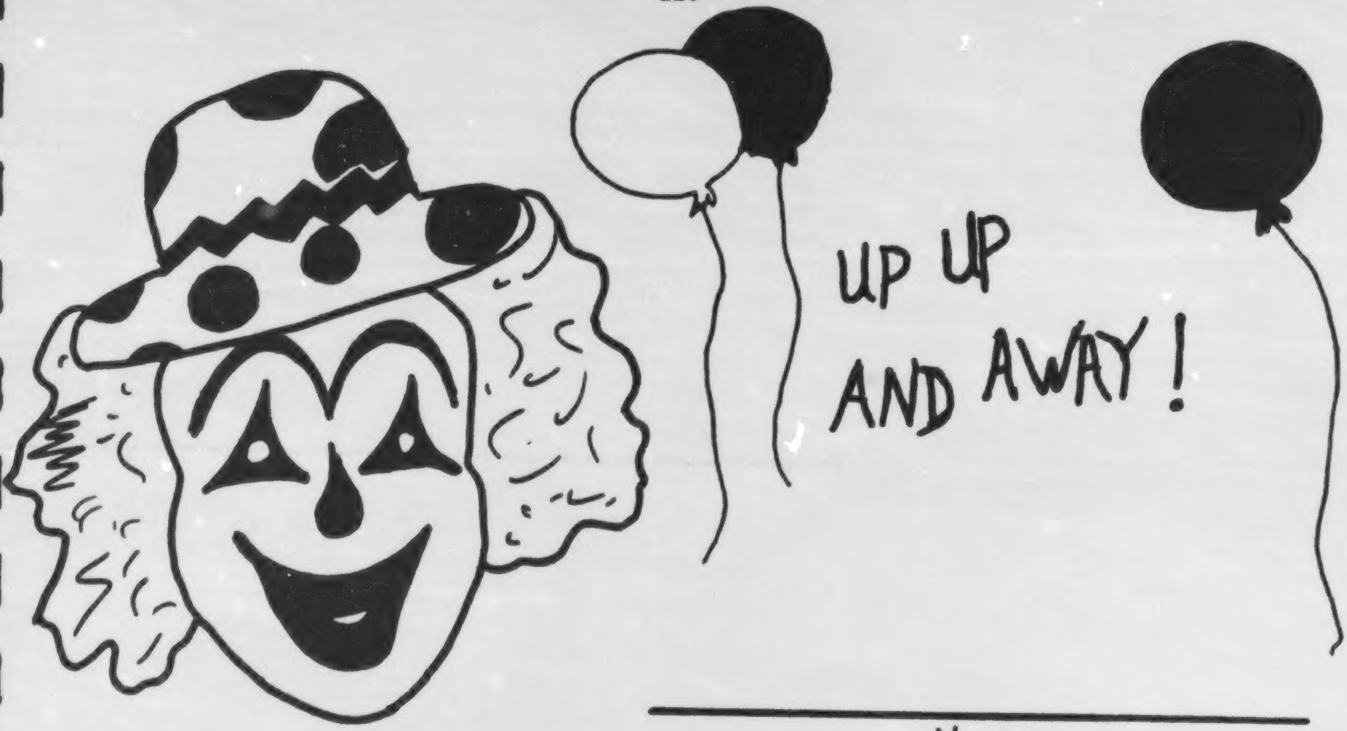
____



TRAVELED ___ LIGHT YEARS

C.A.I.-PEANUTS GRAND PRIX


YOU TRAVELED
___ MILES
SNOOPY



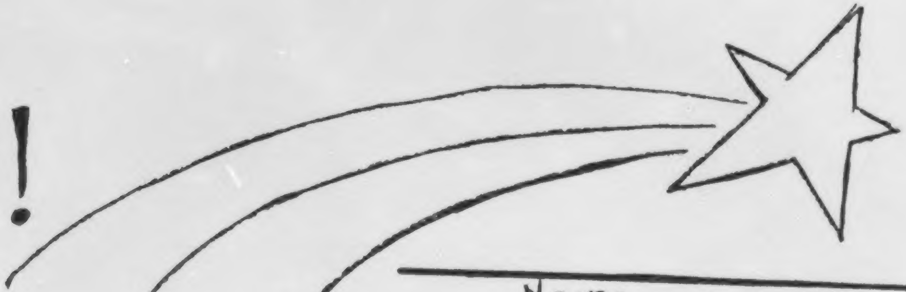
____
Name

Course	Monday	Tuesday	Wednesday	Thursday	Friday
Problem					
Correct					
%					
Problem					
Correct					
%					
Problem					
Correct					
%					
Problem					
Correct					
%					

NAME ROOM TIME COURSE

1.	M	T	W	T	F	2.	M	T	W	T	F	
PROB.						PROB.						
C						C						
%						%						
PROB.						PROB.						
C						C						
%						%						
3.	M	T	W	T	F	4.	M	T	W	T	F	
PROB.						PROB.						
C						C						
%						%						
PROB.						PROB.						
C						C						
%						%						

Aim for the Stars!

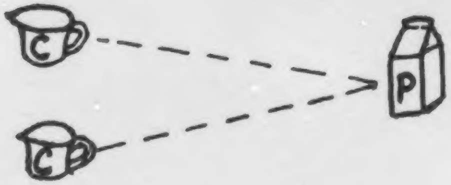


____

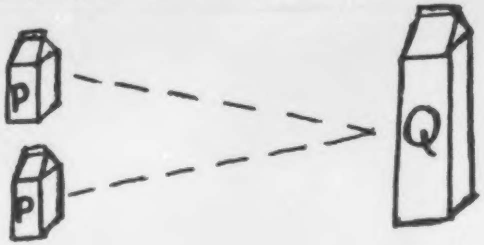
Name

	Monday		Tuesday		Wednesday		Thursday		Friday	
Problems										
Correct										
%										
Problems										
Correct										
%										
Problems										
Correct										
%										
Problems										
Correct										
%										
Course										

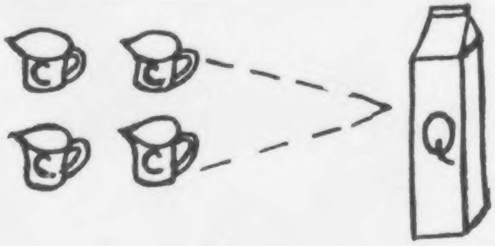
VOLUME



2 CUPS = 1 PINT



2 PINTS = 1 QUART



4 CUPS = 1 QUART

WEIGHT

16 OZ = 1 LB
1000 GM = 1 KG

LENGTH

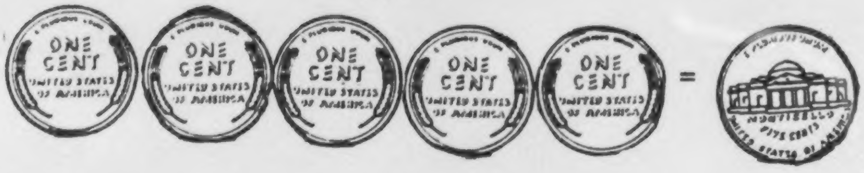
10 MM = 1 CM
100 CM = 1 M
1000 M = 1 KM
12 IN = 1 FOOT
3 FT = 1 YARD

TIME

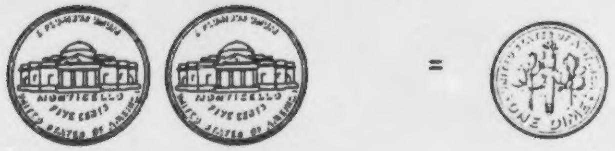
60 MINUTES = 1 HOUR

12
1
2
3
4
5
6
7
8
9
10
11

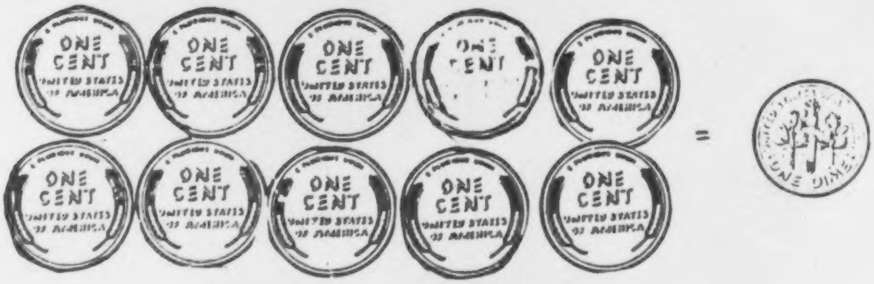
MONEY



5 PENNIES = 1 NICKEL



2 NICKELS = 1 DIME



10 PENNIES = 1 DIME

PART 3*

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

THE CAI CURRICULUMS

*This appeared as Part 3 of M. Ragosta, P. W. Holland, and D. T. Jamison Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report to the U. S. National Institute of Education, April 1982.

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Chapter I

THE CAI CURRICULUMS

In searching for CAI curriculums for use in this study, it became obvious that there were no reading or language curriculums, immediately available, which could be offered to students across grade levels 1-6. Computer Curriculum Corporation (CCC) could provide *Reading, Grades 3-6* and *Language Arts, Grades 3-6*, but lack of audio signals on their systems precluded offering a curriculum for beginning readers. CCC could also provide *Mathematics Strands, Grades 1-6* in the same software package as their reading and language programs. The decision was made to use these off-the-shelf curriculums for several reasons:

(1) They were CAI curriculums which were immediately available, having had fairly wide usage in systems located across the United States.

(2) The CCC curriculums--especially the Mathematics Strands--had a body of evaluation studies which, although they had shortcomings, appeared to indicate success in raising test scores.

(3) CCC was the only vendor which could offer all three curriculums in one software package, at a price the study could afford. Having one software package assured the study of a minimum amount of time to get the CAI operations running.

The CCC curriculums are drill and practice curriculums which are not intended to teach students but to reinforce the skills they have already been taught in the classroom.

A brief description of each of the curriculums follows:

Mathematics Strands, Grades 1-6

Mathematics Strands, Grades 1-6 is one of the most highly individualized CAI (computer-assisted instructional) programs ever developed. A student participating in the Mathematics Strands program receives lessons that are prepared for him on the basis of his own achievement and educational needs. His lessons are not stored in the computer's memory but are generated by the computer as he works at a terminal. Because the computer immediately checks the student's response to each item, it can adjust the lesson's difficulty level while the lesson is in progress. Furthermore, it can make this adjustment in each concept area on which the student is working. Such individualizing capability represents a significant step forward in the development of curriculum material that meets the goals of individualized instruction.

All the topics in elementary school mathematics, with the exception of geometry and work problems, are included in the Mathematics Strands program. Its stress on basic computational skills makes it compatible with a wide range of textbook series. Because it does provide individualization, the program is appropriate for both remedial and accelerated classes.

The Mathematics Strands program achieves its goal of individualized instruction by using a strands structure. There are fourteen strands, one for each concept area included in the program. The strands are:

Strand 1	Number Concepts
Strand 2	Horizontal Addition
Strand 3	Horizontal Subtraction
Strand 4	Vertical Addition
Strand 5	Vertical Subtraction
Strand 6	Equations
Strand 7	Measurement

Strand 8	Horizontal Multiplication
Strand 9	Laws of Arithmetic
Strand 10	Vertical Multiplication
Strand 11	Division
Strand 12	Fractions
Strand 13	Decimals
Strand 14	Negative Numbers

During every session, the student receives a mixture of items from all the strands that have exercises at his grade level. The student's work in each of the fourteen strands is individualized to meet his educational needs. In addition, the computer adjusts the proportion of exercises from each strand to match the proportion of exercises covering that concept in an average textbook.

Reading, Grades 3-6

Reading, Grades 3-6 offers a supplemental reading program with two important features: a high degree of individualization, and a means of diagnosing class and individual reading weaknesses. Both these features make the program a useful tool in building toward the goal of individualized instruction.

The program consists of practice items designed to sharpen the student's reading skills in five areas: word analysis, vocabulary extension, comprehension of sentence structure, interpretation of written material, and development of study skills. It contains enough material for four years of work at grade levels 3, 4, 5, and 6, as well as supplementary remedial material that extends to grade level 2.5.

Each student moves through the program at his own pace. The difficulty of the material he receives is tailored to his own achievement level and is not affected by the performance of other students in the class. If a student needs remedial work, the program moves him to a lower grade level. If a student needs to advance to more challenging material, the program moves him forward rapidly. The students in a given class may spread in grade placement over every grade year the program covers.

The program uses a strands structure to individualize each student's lessons. Each of the five skill areas the program includes is represented by a strand, or graduated sequence of related items. The strands are:

Strand A	Word Attack
Strand B	Vocabulary
Strand C	Literal Comprehension
Strand D	Interpretive Comprehension
Strand E	Work-Study Skills

If the student is doing very well in one area, he moves forward rapidly in the strand which contains items from that area. If he is performing poorly in one area, he is moved back in that strand until he reaches a level that is suited to his abilities. At this point he can begin to move forward again. His rate of movement in each strand is not affected by his position or rate of movement in the other strands.

The program was designed with low reading levels in mind. It begins with very simple vocabulary and adds words from carefully selected vocabulary lists. The lists concentrate on words that children encounter in reading materials and daily life situations.

A special section at the lowest levels of the program contains basic two- to five-word sentences. It is included as remedial work for those students in any school grade who may need it. The material in this section is not differentiated into strands.

Reading for Comprehension

The Reading for Comprehension curriculum is a newer version of the reading curriculum which has already been described. The section on basic sentences has been removed and a new paragraph strand added. Each grade level of Reading for Comprehension contains 100 paragraphs with associated questions.

Reading for Comprehension consists of the following 6 strands:

A. Word Attack — analyzing words as units

B. Vocabulary — building a reading vocabulary

C. Literal Comprehension — understanding the literal meaning of sentences

D. Interpretive Comprehension — learning to read between the lines; developing critical reading skills

E. Word-Study Skills -- learning to alphabetize and to use resources effectively

P. Paragraphs -- integrating skills to read an entire paragraph and answer related questions.

Language Arts, Grades 3-6

Language Arts, Grades 3-6 attacks today's most common language usage problems. It covers grades three through six with enough material for a year's work at each grade level. In addition, it offers supplementary material designed for students with special language problems: hearing-impaired students and students for whom English is a second language.

Language Arts, Grades 3-6 supplements almost any language arts textbook or teaching method. It stresses usage instead of grammar and uses very few grammatical terms. Students using the program learn by example, pattern, and practice.

The program has two sections, strands and topics. In the first year of this study, only the strands section was used. The strands section supplies individualized drill and practice tailored to each student's achievement level. In the topics section, students receive lessons on a topic assigned by their teacher.

The strands section consists of eight strands, or strings of items. Each strand covers grades three through six. The program keeps records of each student's performance in every strand and uses this information to adjust the student's level in each strand. The strands are:

Strand A	Principal Parts
Strand B	Verb Usage
Strand C	Subject-Verb Agreement
Strand D	Pronoun Usage
Strand E	Contractions, Possessives, and Negatives
Strand F	Modifiers
Strand G	Sentence Structure

The Curriculums in the Study

The Mathematics CAI curriculum was used at all grade levels of elementary school. Kindergarten students were not a part of the study but did use the CAI lab in one school on a regular basis. First graders quickly learned to use the equipment and were challenged by the Mathematics curriculum. Only two students in the 4 years of the study topped out of mathematics strands curriculum: both were girls and both had received one or two sessions of mathematics daily across 4 grade levels.

The Language curriculum was used in grades 3-6. A few third graders were non-readers or Spanish-speaking and could not understand or benefit from the Language curriculum. Many sixth graders topped out of the Language curriculum.

The Reading curriculum was used in grades 4-6. It was even harder for non-readers or Hispanic children to access even at grade 4, but fewer sixth graders topped out of reading than out of language. The newer Reading for Comprehension curriculum was used only in grade 4 in the final year of the study. It also proved difficult for students of low reading ability.

Summary

In this chapter we have briefly described the 4 CAI curriculums used in this study. For further information and descriptions of the CAI curriculums, the Computer Curriculum Corporation of Palo Alto, California, may be contacted.

Chapter II

TIME ON THE COMPUTER

In this chapter we will examine the amount of exposure to CAI experienced by students in the study; we will examine the question of whether students assigned to high or low levels of a curriculum actually received high or low levels of CAI experience in that curriculum; and we will examine whether the amount of CAI time differed with student characteristics such as sex or ethnicity.

We have selected specific data bases for analysis. The grade 4, year 4 data was selected because it contained the largest data base for any single year and grade level. The three longitudinal data bases were also selected because of their importance to the study.

Total Time on the Computer

Each year except for the first year of the study, students started work in the CAI lab about the middle of October and ended about the middle of June. During that period of time--barring exceptions--students assigned to one session of CAI daily received 50 minutes of CAI each week, while students assigned two sessions received 100 minutes weekly. There were exceptions, however. There were holidays, early closings, assemblies, school trips, fire drills, and computer breakdowns as well as student absences. Two questions concern us. How much variability exists among students assigned a specific amount of CAI? How much CAI did the average student receive?

Grade 4, Year 4. Students in grade 4 in the final year of the study were assigned one 10-minute session of CAI daily in 1 of 4 CAI curriculums: mathematics, reading, language, or reading for comprehension. The boxplot shown in Figure 1 indicates that students in each of the four curriculums received about 900 minutes (or 90 sessions) of CAI during the school year. Fifty percent of the students in each curriculum--those between the lowest quartile and the upper quartile--received between 80 and 100 sessions of CAI during the year. Some students received less than 500 minutes of CAI while others received up to 1300 minutes. Despite the wide range of individual differences in exposure to CAI, the differences across treatments are so minimal as to be practically nonexistent.

```
TIME ON COMPUTER FOR SCHOOLS

SUMMARY STATISTICS

GROUP          N      MIN          LOQ          MEDIAN       HIQ          MAX              MEAN         S.D.

MATH         130    386.0000     826.0000     920.0000    1000.0000    1304.0000        904.5538     155.5509
READING      105    185.0000     812.0000     910.0000     982.0000    1142.0000        886.1333     146.8448
LANGUAGE      67    420.0000     805.0000     887.0000    1007.0000    1249.0000        894.4328     156.5765
COMPRHEN      40    299.0000     831.5000     942.5000     987.5000    1059.0000        887.4750     158.6610
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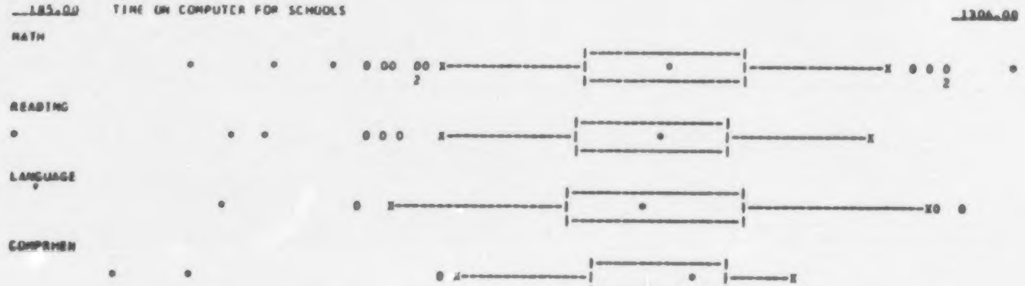


Figure 1. Time on Computer: All Curriculums: Grade 4

KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
0 FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR 0 AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL

Grades 1-3. In this longitudinal CAI cohort, students were randomly assigned by classrooms to mathematics CAI during grades 1 and 2. In grade 3, students were randomly assigned within classrooms to mathematics or language CAI. Over the three years, some students received CAI for only one year while others received CAI for two or three years or not at all. Our concern with this cohort is whether, in fact, students received two or three times the one-year treatment levels if they were assigned to CAI for two or three years. In Figure 2, we see that students who received two or three years of mathematics CAI did, in fact, get slightly more than two or three times the amount of CAI--on the average--as the one-year group. One-year students averaged 93 sessions; two-year students averaged 197 sessions; and three-year students averaged 288 sessions.

```
TIME BREAKDOWN BY TREATMENT

SUMMARY STATISTICS

GROUP          N        MIN          LOQ         MEDIAN        MIQ          MAX            MEAN         S.D.

1MATH         40      80.0000     763.5000    1000.5000    1094.0000    1306.0000       932.6250    276.3472
2MATH         42     874.0000    1794.0000    1985.5000    2196.0000    2627.0000      1977.0238    340.0848
3MATH         18    1623.0000    2702.0000    2996.0000    3217.0000    3617.0000      2887.0000    478.6509
```

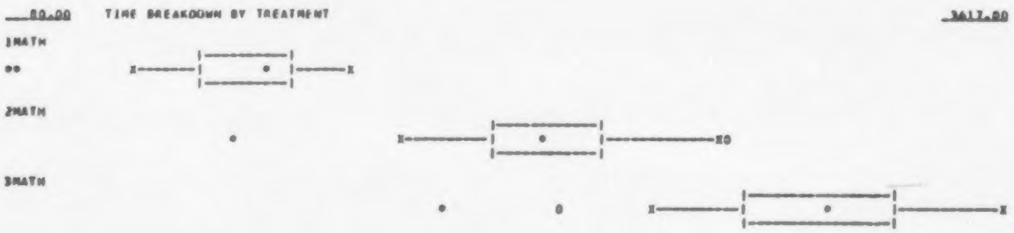


Figure 2. Time on Computer by Treatment: Grades 1-3: Math

```
     KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
O FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR O AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL
```

Grades 3-5. Students in this longitudinal CAI cohort were exposed to one of two treatment conditions. Students who were randomly assigned to two sessions of mathematics CAI (MM) in grade 3 continued with that treatment through grade 5. Other students, who had been randomly assigned to one session of mathematics and one session of language arts in grade 2 (ML), received one session of reading and one of language (RL) in both fourth and fifth grade. Our concern with this CAI cohort is whether the MM group and the ML/RL group received equal amounts of time on the computer over the three years. Figure 3 shows almost identical amounts of time for the two groups: each group received on the average slightly more than 500 10-minute sessions on the computer.

```
TIME BREAKDOWN BY TREATMENT

SUMMARY STATISTICS

GROUP      N    MIN         LQ          MEDIAN      UQ          MAX          MEAN         S.D.

MM         61   3724.0000   4584.0000   4838.0000   5434.0000   6807.0000    5041.2623    737.6953
ML/RL      34   3875.0000   4511.0000   5022.5000   5494.0000   6681.0000    5054.2353    680.3170
```

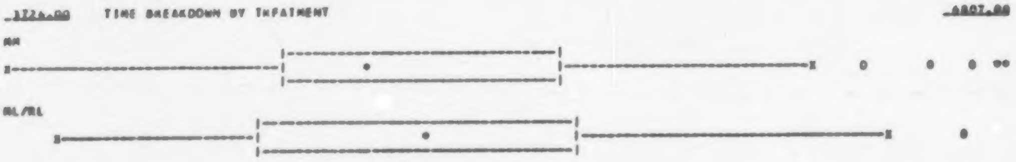


Figure 3. Time on Computer by Treatment: Grades 3-5

```
     KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
0 FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR 0 AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL
```

Grades 4-6. Students in this longitudinal CAI cohort received two 10-minute sessions of CAI daily for three years. They were randomly assigned to mathematics (MM), reading and language (RL), or mathematics and alternating sessions of reading and language (MRL). Figure 4 indicates the relative amounts of time on the computer for each of the three treatment conditions. Although the RL group received less CAI time, only 25 or 30 sessions (12-15 days) of CAI separate the RL group from the others. We will take a closer look at this CAI cohort to determine whether differences in the levels of treatment threaten the research design.

Figure 4. Time on Computer by CAI Treatment: Grades 4-6

```
TIME BREAKDOWN BY TREATMENT

SUMMARY STATISTICS

GROUP          N      MIN          LOQ          MEDIAN       MIQ          MAX            MEAN         S.D.

MM            29    3267.0000    4543.0000    4925.0000    5462.0000    6650.0000      4928.6897    842.8944
MRL           28    3047.0000    4501.5000    5075.5000    5452.5000    6178.0000      4854.8929    756.9432
RL            29    3154.0000    3949.0000    4749.0000    5356.0000    6049.0000      4682.9310    842.2008
```

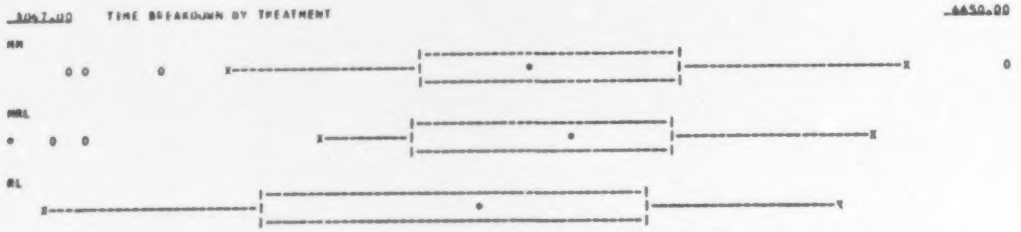


Figure 4. Time on Computer by CAI Treatment: Grades 4-6

```
    KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
O FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR O AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL
```

Levels of CAI Treatment

The research design provided for an MRL group in the grades 4-6 CAI cohort because the MRL group represented an intermediate treatment condition between the MM group and the RL group. With regard to mathematics, for instance, the RL group received zero sessions, the MRL group received one session daily, and the MM group received two sessions daily. It was important to the research design that the MRL group receive about half the CAI time in the curriculums as other groups. In Figure 5 we see that those conditions were met. In mathematics the MM group took an average of 493 sessions while the MRL group took 248. The RL group took 239 sessions of reading while the MRL group took 119. In language CAI, the RL group took 222 sessions while the MRL group took 118.

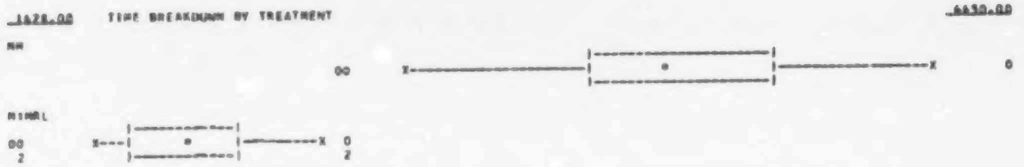
The language curriculum was easier to complete than the other CAI curriculums in this study. More students topped out of language and were unable to accumulate additional time in that curriculum. That fact could help to explain the slightly depressed score for the RL group in language. If the RL group had had 235 or 240 sessions, the groups would have been more nearly equivalent. However, students who topped out of language were, in fact, enrolled in language topics—a variation of the CAI language curriculum. Records were not kept of how much time was spent in topics, but that treatment was used to maintain the conditions of the research design.

Since the conditions of the research design were met and students assigned to different levels of CAI treatment actually obtained those different levels, the results of the effectiveness studies have not been compromised. We now turn our attention to whether the amount of CAI time differed with the sex or ethnicity of CAI students.

TIME BREAKDOWN BY TREATMENT

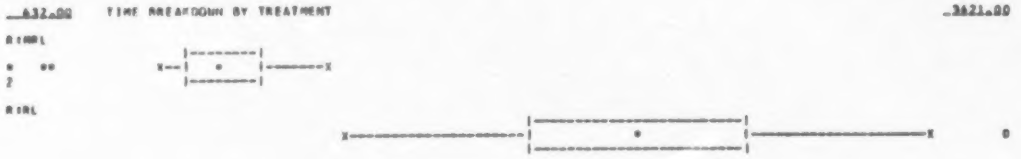
SUMMARY STATISTICS : MM vs MRL: Time on Mathematics

GROUP	N	MIN	LOQ	MEDIAN	HIQ	MAX	MEAN	S.D.
MM	29	3267.0000	4343.0000	4925.0000	5462.0000	6650.0000	4928.6897	842.8944
M:MRL	28	1628.0000	2224.0000	2532.5000	2752.0000	3306.0000	2484.2143	434.9304



SUMMARY STATISTICS : RL vs MRL: Time on Reading

GROUP	N	MIN	LOQ	MEDIAN	HIQ	MAX	MEAN	S.D.
R:MRL	28	632.0000	1113.5000	1273.0000	1336.0000	1533.0000	1187.4643	235.2286
R:RL	29	1575.0000	2082.0000	2387.0000	2686.0000	3421.0000	2386.7931	485.5998



SUMMARY STATISTICS : RL vs MRL: Time on Language

GROUP	N	MIN	LOQ	MEDIAN	HIQ	MAX	MEAN	S.D.
L:MRL	28	698.0000	1108.5000	1217.0000	1304.5000	1440.0000	1183.2143	178.8008
L:RL	29	1070.0000	1918.0000	2345.0000	2514.0000	3072.0000	2216.1379	463.1194

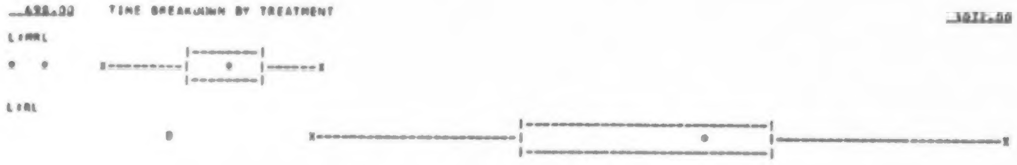


Figure 5. Levels of CAI Treatment in Mathematics, Reading & Language

KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
0 FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR 0 AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL

CAI Time by Sex

Time breakdown by treatment and sex for students in grade 4, year 4, shows that, at most, only five sessions separates the means of males and females in any of the four curriculum assignments. The greatest difference occurs for the language curriculum, and topping out may have affected those means slightly. When boxplots were run on the time breakdown for longitudinal CAI cohorts no discernible sex pattern emerged.

CAI Time by Ethnicity

Time on the computer by treatment and ethnicity for mathematics, reading and language CAI students in grade 4, year 4, is presented in Figure 6. A disturbing pattern emerges showing lesser amounts of CAI time for Black students than for Hispanics or others. That pattern frequently repeats itself for students in the longitudinal CAI cohorts. In grades 4-6 the Hispanic students received less time in the MM and MRL conditions than did Black students but, in general, Blacks obtained the lowest times, Hispanics the median amounts of time, and other students the most time. Since ethnicity and schools were confounded to a large extent in this study, further analyses were done plotting treatment by school. School 3, which was predominantly Black, had the lowest CAI time; School 4, which had the largest Hispanic population, was next; and School 2, whose population was to a large extent White, had the highest CAI times.

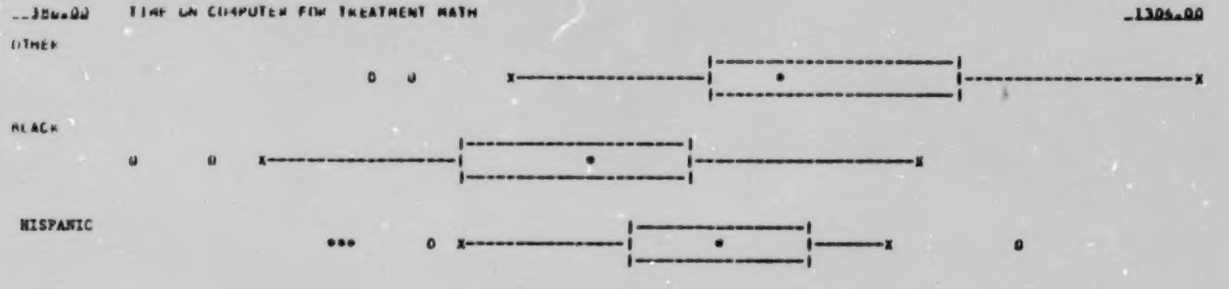
Since the research design called for random assignment of students to curriculums within schools, ethnicity should be randomly distributed across treatment conditions. Nevertheless, both sex and ethnicity variables have been used as covariates in all regression analyses to be reported in this study.

```
TIME ON COMPUTER FOR TREATMENT MATH

SUMMARY STATISTICS:  MATH

GROUP          N      MIN         LOQ         MEDIAN       HIQ          MAX           MEAN        S.D.

OTHER         34   642.0000    926.0000    980.0000    1122.0000    1304.0000     1001.1471    149.6642
BLACK         47   386.0000    737.0000    837.0000     911.0000    1091.0000      816.7234    149.7548
HISPANIC      49   637.0000    861.0000    936.0000    1000.0000    1163.0000      921.7755    113.8867
```

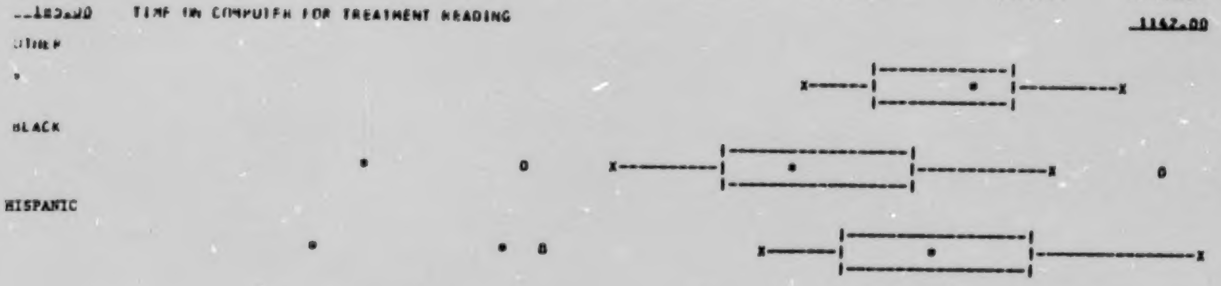


```
TIME ON COMPUTER FOR TREATMENT READING

SUMMARY STATISTICS:  READING

GROUP          N      MIN         LOQ         MEDIAN       HIQ          MAX           MEAN        S.D.

OTHER         27   185.0000    873.0000    956.0000     990.0000    1075.0000      917.0000    160.5733
BLACK         36   467.0000    757.5000    816.0000     908.5000    1113.0000      829.8056    126.9437
HISPANIC      42   428.0000    849.0000    924.5000    1006.0000    1142.0000      914.5714    139.2114
```



```
TIME ON COMPUTER FOR TREATMENT LANGUAGE

SUMMARY STATISTICS:  LANGUAGE

GROUP          N      MIN         LOQ         MEDIAN       HIQ          MAX           MEAN        S.D.

OTHER         10   795.0000    840.0000    934.0000    1152.0000    1209.0000      978.6000    146.6617
BLACK         37   571.0000    804.0000    849.0000     932.0000    1127.0000      862.0270    118.7108
HISPANIC      20   420.0000    801.5000    905.0000    1044.5000    1249.0000      912.3000    198.7456
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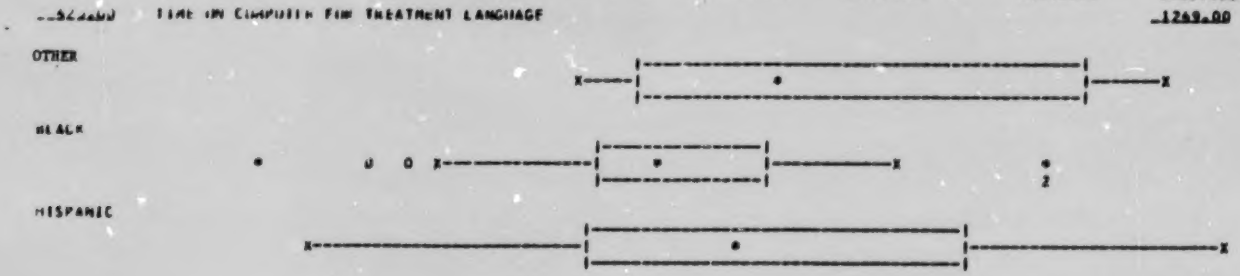


Figure 6. Time Breakdown by Treatment and Ethnicity: Grade 4, Year 4.

Summary

In this chapter we have examined the amount of exposure to CAI experienced by students in the study. Although there was great variability in the total amounts of CAI time for individual students, the overall differences across treatment groups were minimal. Where students were assigned different levels of CAI exposure in the study they received different levels of exposure. Although no consistent differences in CAI time were found between males and females, differences were found between minority students and others. Lower CAI times for Black students were related to lower CAI times in one predominantly Black school.

Chapter III

CURRICULUM PLACEMENT

The CAI curriculums have been described as adapting to the ability levels of various students. In this chapter we will take a closer look at those claims. We will examine the rapid motion which is in effect during the first 10 sessions of a CAI curriculum; we will take a close look at the initial curriculum placement for students in grade 4, Year 4; and we will take an arbitrary entry level for the mathematics curriculum and see what kinds of students at what grade levels are represented by that starting point.

Rapid Motion

The CAI curriculums used in this study can adjust each student's grade level up or down in half-year steps. This rapid adjustment of grade level is called initial placement motion. It comes into effect only during the first 10 sessions and only if a student performs very poorly or very well at the entering grade level.

Students who answer 50% or fewer of the items correctly during any of the first ten sessions move back a half year: for example, from an entering grade level of 4.0 to a new grade level of 3.5. Students who answer 95% or more of the items correctly move forward a half year: for example, from grade level 4. to grade level 4.5.

The initial placement motion is one of the individualizing elements of the program. It ensures that students work at the level appropriate to their ability.

To illustrate rapid motion we asked Jezebel--a fifth-grade student, one of the only two students who topped out of the mathematics CAI curriculum--to try to top out of mathematics within 10 sessions starting from three

Table 3-1

The Rapid Motion Progress of Jezebel from Three Entry-Level Placements

					SESSIONS							
	Start	1	2	3	4	5	6	7	8	9	10	
#801												
PROGRESS: TIME	0	:10	:20	:30	:40	:50	1.00	1:10	1:20	1:30	1:40	
# ATTEMPTED		65	49	52	48	46	46	63	49	60	49	
# RIGHT		64	43	45	43	40	36	59	40	50	47	
% RIGHT		98	88	87	90	87	78	94	82	83	96	
AND PLACEMENT $\bar{X}$	6.0	6.5			6.6		6.7		6.8		7.0	
RANGE: FROM		6.5			6.5		6.5		6.5		6.6	
TO		6.6			6.8		7.0		7.2		7.4	
#802												
PROGRESS: TIME	0	10	:20	:30	:40	40	50	1:00	1:10	1:20	1:30	1:40
# ATTEMPTED		68	57	57	47	0	59	54	53	57	62	46
# RIGHT		66	54	51	41	0	54	53	49	50	59	39
% RIGHT		97	95	89	87	0	92	98	92	88	95	85
AND PLACEMENT $\bar{X}$	5.0		6.0			6.0		6.6		6.6		7.2
RANGE: FROM			6.0			6.0		6.6		6.5		7.2
TO			6.0			6.2		6.6		6.8		7.2
#803												
PROGRESS: TIME	0	:10	:20	:30	:40	:50	1:00	1:10	1:20	1:30	1:40	
# ATTEMPTED		107	114	109	109	100	82	71	67	69	57	
# RIGHT		99	107	102	100	92	77	63	64	62	52	
% RIGHT		93	94	94	92	92	94	89	96	90	91	
AND PLACEMENT $\bar{X}$	4.0		4.1		4.2		4.4		5.0		5.0	
RANGE: FROM			4.0		4.0		4.1		5.0		5.0	
TO			4.3		4.5		4.9		5.0		5.4	

different entry levels. Table 3-1 indicates Jezebel's progress and placement on her three attempts. As student #801 she entered the curriculum at level 6.0 and after session #10 she had a mean curriculum placement of 7.0, with strand placement ranging from 6.6 to 7.4. Only twice did she get more than 95% of her questions correct while she averaged 53 attempts each session.

On her second try—beginning from a curriculum-placement of 5.0—Jezebel did better. On four occasions in her first 10 sessions she got 95 percent or more of the questions correct and her final placement (at the end of 11 sessions) was 7.2. An interesting phenomenon is illustrated in Jezebel's second attempt. After she had worked for 20 minutes on day 2 as student #802, she signed on for a third session of mathematics. She immediately realized she should only have done two sessions, and she stopped her lesson before she had answered a question. The computer counted it as session #5 and scored her zero. Despite that, Jezebel made a jump of 2.2 curriculum levels in her first hour and forty minutes. When the nine meaningful sessions were averaged, Jezebel had attempted a mean of 53 questions per session—the same number of attempts as in her first round of sessions.

As student #803 Jezebel attempted to top out in 10 sessions starting from level 4.0 of the mathematics CAI curriculum. Only once in this set of records did she reach 95% or better. The mean number of questions attempted on this try reached more than 88. Her final placement was a discouraging 5.0.

One can see from Jezebel's reports that rapid motion does work. If high percentages of correct scores are obtained, the movement is rapid. It is unfortunate, perhaps, that the first 10 sessions of a CAI curriculum come at a time when students find it easy to make errors because of unfamiliarity with the system. Errors are easy to make even for an expert with the system like Jezebel.

Fall CAI Placement: Grade 4

Students entering grade 4 in Year 4 had never been exposed to computer-assisted instruction although many of them had taken the curriculum-specific tests (CSTs) developed from the CAI curriculums. Figure 7 gives a good indication of the variability of entry-level placement after rapid motion.

Differences among curriculums. Of the three CAI curriculums in general use in the study—mathematics, reading and lanaguage —conventional wisdom was that language was the easiest and mathematics was most difficult. There were several kinds of observations to this effect. During the first year of the study, sixth-grade students topped out of language more frequently than out of reading. Fourth-grade students had less difficulty with language. The 100% Club more frequently acquired members from groups assigned to reading and language than to mathematics. Figure 7 may be giving another bit of evidence for the conventional wisdom. Since students were randomly assigned to curriculums, one would expect the mean entry levels of equally difficult curriculums to be approximately equal.

```
FALL PLACEMENT   FOR SCHOOLS

SUMMARY STATISTICS

GROUP           N       MIN          LOQ         MEDIAN         HIQ          MAX            MEAN        S.D.

MATH          131    150.0000     370.0000     371.0000     430.0000     630.0000       380.5573     94.8756
READING       109    250.0000     370.0000     420.0000     502.0000     680.0000       433.5321     88.4562
LANGUAGE       67    320.0000     430.0000     500.0000     590.0000     700.0000       506.4179     96.7024
COMPRHEN       40    324.0000     375.5000     443.0000     500.0000     700.0000       452.3500     88.8945
```

```
__150.00    FALL PLACEMENT   FOR SCHOOLS                                                                         __700.00
MATH
                                      |-----------------------|
*     0     0   X---------------------|          *            |-----------------------X 0000   0  0   *   *
                                      |-----------------------|                            3
READING
                                                 |----------------------------|
                       X-------------------------|         *                  |--------------------------X         0 0
                                                 |----------------------------|
LANGUAGE
                                                              |----------------------------------|
                                      X-----------------------|               *                  |-----------------------X
                                                              |----------------------------------|
COMPRHEN
                                                  |---------------------------|
                                       X----------|             *             |--------------------------X               *
                                                  |---------------------------|
```

Figure 7. Fall Placement for Schools: All Curriculums: Grades 4

```
        KEY:
BOX EXTENDS FROM LOWER TO UPPER QUARTILE, WITH * AT MEDIAN
X AT MOST EXTREME POINTS LYING WITHIN ONE INTERQUARTILE RANGE (IQR) OF EACH QUARTILE
O FOR EACH POINT LYING BETWEEN 1 AND 1 1/2 IQR FROM EACH QUARTILE
* FOR EACH POINT LYING MORE THAN 1 1/2 IQR FROM EACH QUARTILE
MULTIPLICITY FOR O AND *, IF ANY, NOTED DIRECTLY UNDER SYMBOL
```

Entry levels range from a low mean of 3.8 in mathematics, through means of 4.3 and 4.5 in the two reading curriculums, to a high mean of 5.1 in the language curriculum.

Differences among students. The wide range of ability levels of students in grade 4 in the CAI schools is apparent from the wide range of entry levels in each of the four CAI curriculums seen in Figure 7. In mathematics, students began their drill-and-practice program as low as level 1.5 or as high as 6.3. Minimums in reading, language and comprehension were 2.5, 3.2, and 3.2, respectively, while maximums were 6.8, 7.0, and 7.0. The low of 2.5 in reading and the highs of 7.0 in language and comprehension represent end points in those curriculums. Even at grade 4 some students could barely access the reading curriculum. Non-readers and non-English speaking children had difficulty with the language curriculum as well as the reading and comprehension curriculums. Other grade 4 students reached the upper limit of these curriculums and topped out within the first 10 sessions. The fact that some students had difficulty accessing the curriculums while other students topped out is a severe limitation of the reading and language CAI curriculums. Although they appear to span several grade levels, they were not broad enough to accommodate the range of skills of students in grade 4 in our CAI schools. The mathematics curriculum, on the other hand, could accommodate students from kindergarten to grade 6 with no difficulty. The only two students to top out of the mathematics curriculum had had 20 minutes of mathematics CAI daily for almost four years and were both extremely bright girls.

CAI Placement: The Curriculums

Another way to look at the adaptability of the curriculums to the ability levels of students is to take a specific range of curriculum levels and determine how many students at each grade level have used that entry level. Table 3-2 presents that data for the students in the CAI study. The variation in ability levels of students is demonstrated by the capability of the CAI curriculums to range widely across entry levels even within a specific grade level. Students in the mathematics CAI curriculum, for example, ranged from a low entry level of 1.5-1.9 through the middle ranges to a high entry level of 6.5-6.9.

The breadth of the mathematics CAI curriculum is also demonstrated by Table 3-2. Students entered the curriculum at all grades and had plenty of room to grow. The reading and language programs are more restricted, serving fewer grades at the lower end of the curriculum and providing less extensive coverage at the upper end. Perhaps one of the reasons for the difficulty in assessing the effectiveness of the reading and language curriculums is the fact that the range of ability levels among students was greater than the capacity of the current CAI curriculums in reading and language.

Table 3-2

Numbers of Students by Actual Grade Levels, Entering Each of 3 CAI Curriculums at Varying Entry Levels

	RANGES OF ENTRY LEVEL PLACEMENT													
MATHEMATICS GRADE LEVELS	1.0- 1.4	1.5- 1.9	2.0- 2.4	2.5- 2.9	3.0- 3.4	3.5- 3.9	4.0- 4.4	4.5- 4.9	5.0- 5.4	5.5- 5.9	6.0- 6.4	6.5- 6.9	7.0- 7.4	7.5- 7.9
1	62	53	1											
2	17	112	133	18	1	2								
3	14	68	228	57	23	9	1							
4	3	33	104	78	48	27	3							
5		14	30	40	64	61	30	12	5	2	1			
6		1	12	12	11	14	13	11	14	4	4	1		
READING GRADE LEVELS														
1														
2				(NO STUDENTS WERE ASSIGNED READING BEFORE GRADE 4)										
3														
4				77	59	55	25	21	19	7	2	1		
5				20	16	38	37	38	23	14	3	1		
6				11	11	15	21	26	26	6	4	7		
LANGUAGE GRADE LEVELS														
1														
2				(NO STUDENTS WERE ASSIGNED LANGUAGE BEFORE GRADE 3)										
3					134	23	13	5	3					
4					143	45	20	10	9		1			
5					53	25	32	19	23	7	6	2		
6					10	24	22	9	26	11	10	4		

Summary

In this chapter we have looked at the capability of the CAI curriculums to adapt to the ability of students. We have examined the rapid-motion phase of the curriculums in effect during the first 10 sessions. We have taken a close look at the placement of fourth graders and a broad look at the placement of all CAI students in the study. We turn our attention now to the progress made by students in the CAI curriculums.

Chapter IV

PROGRESS IN CAI CURRICULUMS

Coordinators in the CAI labs reported on their perceptions of progress in the CAI curriculums. As background information their perceptions may be of interest. Coordinators strongly approved the mathematics curriculum and felt that student progress in that curriculum was appropriate and motivating to students. The language curriculum was also motivating and student progress in language arts was relatively fast. Student progress in the reading curriculum, however, was slow and methodical. A few highly motivated students complained at the lack of movement, and coordinators forwarded those complaints to project personnel.

Most students in grades 4-6 were very interested in their own daily success rate and in their weekly progress in CAI. In a drill-and-practice curriculum which varies little over time, a student's progress in that curriculum is a strong motivational tool.

In this chapter we will take a close look at student progress in the CAI curriculums; we will discuss rate of progress by grade and entry level for all CAI students in the study; and we will discuss differences among the curriculums in the light of student progress.

Student Progress

Figures 8 and 9 are graphs of student CAI placement against CAI time and give a visual indication of progress in mathematics, reading and language.

The mathematics curriculum. Figure 8 contains six plots of the mathematics curriculum, one plot at each of the six grade levels. The plots for grades 2, 3, 4 and 5 are especially interesting because they show two levels of assigned CAI treatments in mathematics. In grade 2, year 1, students within classrooms were assigned either 7 (M) or 14 (MM) minutes of mathematics CAI daily. The graph shows the students progressing at about the same rate with the MM group getting a little further along in the curriculum. In grade 3 the groups were reversed, with most MM students assigned to mathematics and language (ML) rather than two sessions of mathematics. Rates of progress for the two groups are similar but the MM group went further into the curriculum. Rather similar results are apparent in grades 4 and 5. Students assigned to double sessions of mathematics (MM) in grade 4, year 1, progressed further in the curriculum than students assigned to mathematics with alternating sessions of reading and language (MRL). When students maintained their CAI treatments in grade 5, the rate of progress for the MM group appears to be widening the differences in curriculum placement.

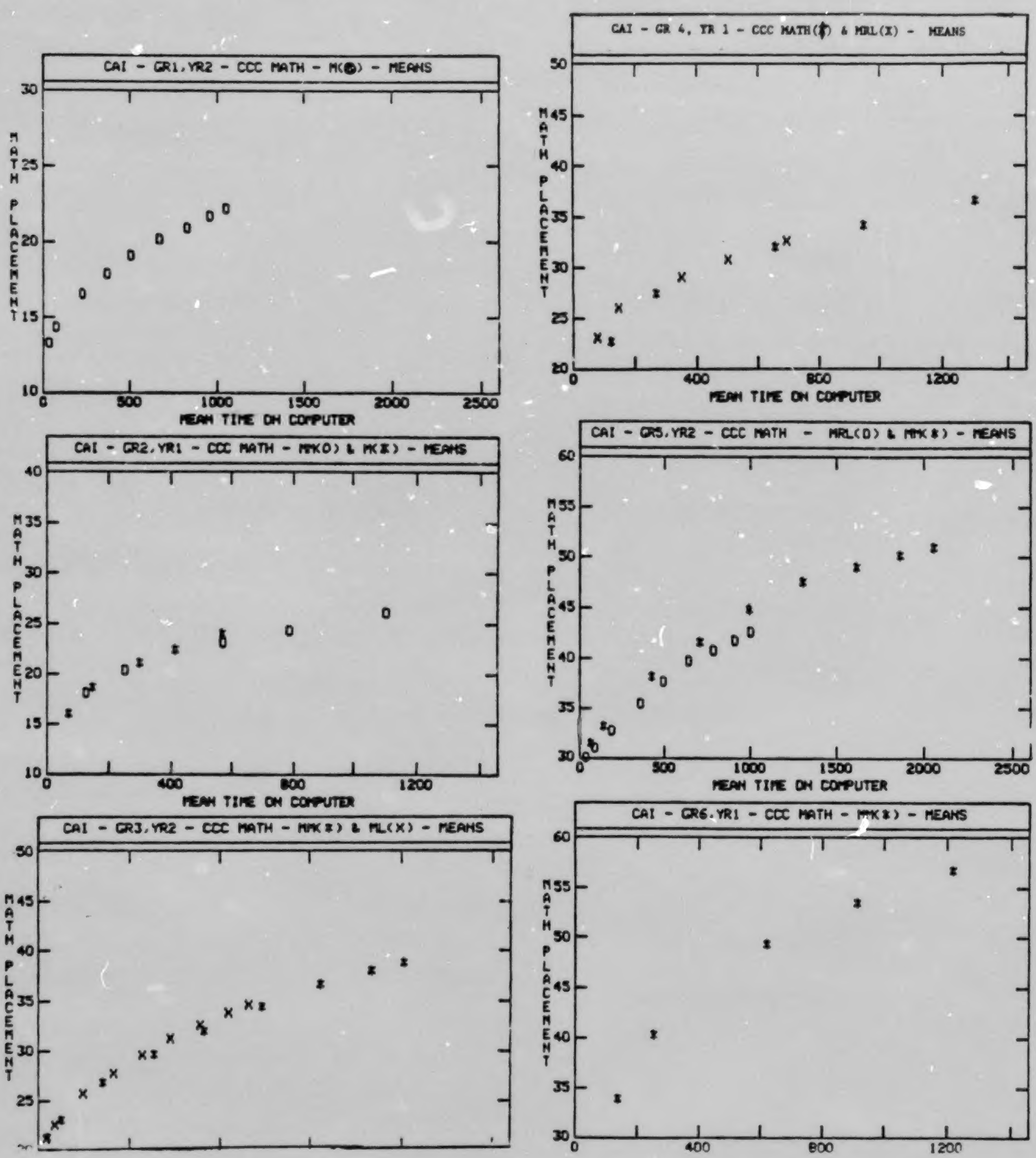
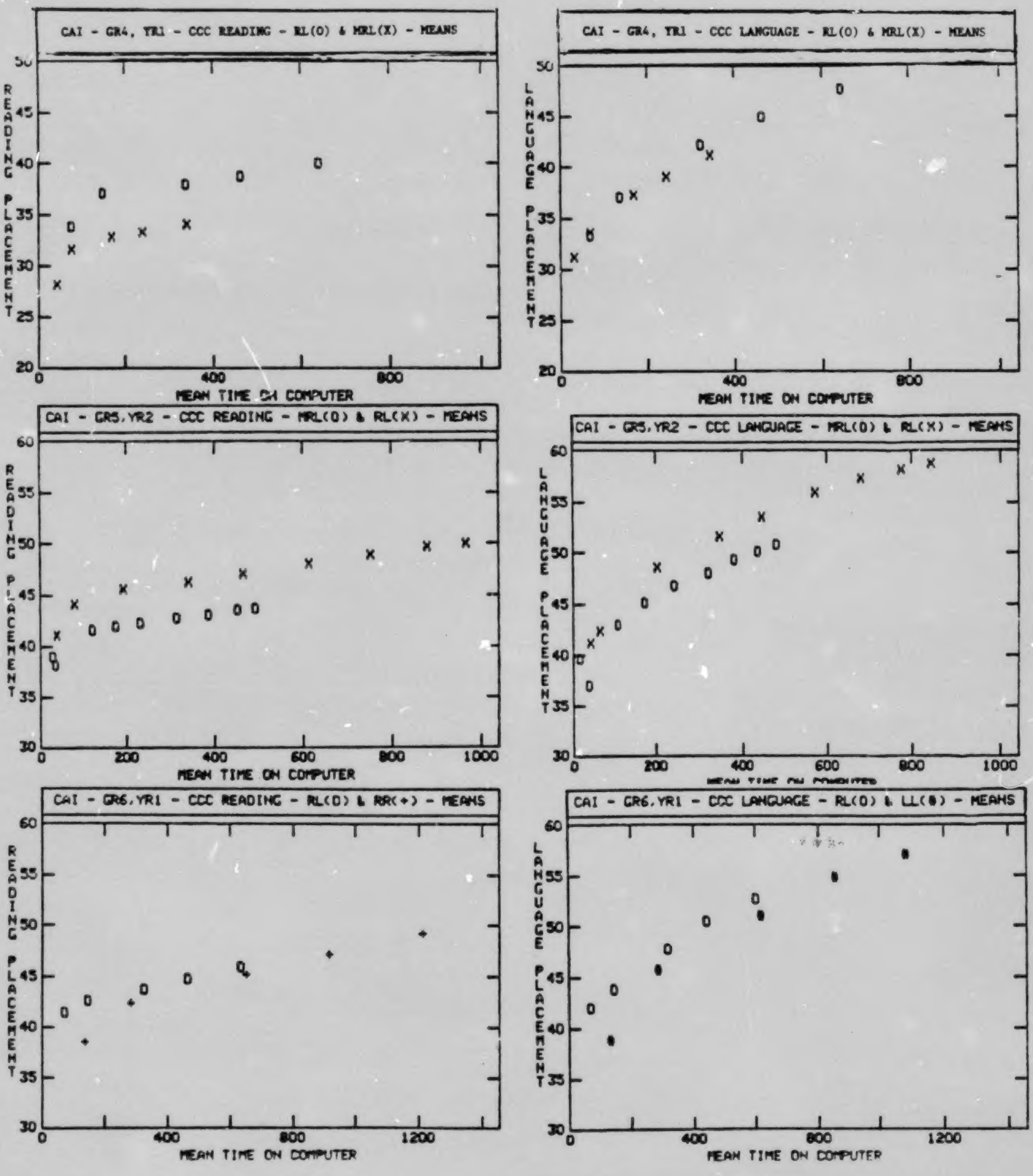


Figure 8. CAI Progress in Mathematics

The reading and language curriculums. In Figure 9 in the reading curriculum we see a different pattern. In grades 4 and 5, students assigned to CAI reading and language curriculums (RL) appear to be progressing at equal rates on parallel paths with the MRL group, except that the RL group is further into the curriculum almost from the beginning. It looks as though rapid motion may have determined the placement of the two groups differently, but after completing the 100 minutes of rapid motion, students in both groups proceeded at approximately equal rates. Why would rapid motion affect the two groups so differently? Perhaps it is because the two groups are less similar than the design intended. In fact, non-readers and predominantly Spanish-speaking children were removed from the RL group when it was determined that the reading and language programs were inappropriate.

In Figure 9, the progress of the same RL and MRL students is portrayed graphically for the language curriculum also. The graphs seem to show the RL students accelerating faster in language than the MRL students. Perhaps one session of language every other day is too little to achieve the maximum rate of progress.



CAI - GR4, YR1 - CCC READING - RL(O) & MRL(X) - MEANS

CAI - GR4, YR1 - CCC LANGUAGE - RL(O) & MRL(X) - MEANS

CAI - GR5, YR2 - CCC READING - MRL(O) & RL(X) - MEANS

CAI - GR5, YR2 - CCC LANGUAGE - MRL(O) & RL(X) - MEANS

CAI - GR6, YR1 - CCC READING - RL(O) & RR(+) - MEANS

CAI - GR6, YR1 - CCC LANGUAGE - RL(O) & LL(*) - MEANS

Figure 9. CAI Progress in Reading and Language Arts.

Rate of Progress

Norm tables for students in this CAI study were made to display entry and exit levels, mean time on computer and rate of progress. The norm tables were further broken down by sex and ethnicity within grade levels. An example of the norm table for mathematics entry level 1.5 to 1.9 is shown in Table 3-3.

Rate of progress as shown in the norm table is defined as curriculum levels attained per 100 minutes of CAI time. It was computed for each student by:

$$\frac{\text{exit level} - \text{entry level}}{\text{exit time} - \text{entry time}} \times 100$$

In Table 3-3 we see that the mean rate at this entry level for all students in grade 1 was .075. With roughly 1000 minutes of CAI time, the average first grader could cover .75 of a curriculum level. In fact, the average first grader at this entry level entered at 1.66 and left at 2.45 with 1041 minutes of CAI time. That information was obtained from the bottom line of the entries for grade 1. Those figures are articulated even further with breakdown by sex and ethnicity: Black, Spanish, and others.

In looking across grade levels, the rate of progress for students entering the math curriculum at level 1.5-1.9 increases to grade 4 and then decreases in grade 5. (The increase in grade 6 is based on one student and should not be considered in looking for patterns in the data.) The higher the rate of progress figures, the farther the student has been able to proceed in the curriculum. The mean exit scores do not show the pattern of increase through grade 4 because of the different amounts of CAI time at the different grade levels.

Table 3-3

Norm Tables for CAI Achievement (LAUSD/CAI)

FOR MATH ENTRY LEVEL 1.5-1.9

STUDENTS	ENTRY			EXIT				TIME ON COMPUTER		RATE	
	N	MEAN	ST-DEV	MEAN	ST-DEV	LO	HI	MEAN	ST-DEV	MEAN	ST-DEV
GRADE 1											
OTHERS	27.	1.681	0.1272	2.515	0.4400	1.4	3.5	1035.3	141.400	0.078	0.042
BLACK	15.	1.660	0.1454	2.407	0.3595	2.0	3.2	1006.5	90.405	0.075	0.037
SPANISH	11.	1.609	0.1221	2.373	0.3289	2.0	2.9	1102.4	46.854	0.069	0.026
MALE	28.	1.643	0.1345	2.432	0.3859	1.4	3.2	1036.3	141.101	0.074	0.039
FEMALE	25.	1.680	0.1291	2.480	0.4123	2.0	3.5	1046.4	85.999	0.077	0.037
TOTAL	53.	1.660	0.1321	2.455	0.3954	1.4	3.5	1041.1	117.376	0.075	0.038
GRADE 2											
OTHERS	22.	1.782	0.1368	2.368	0.5358	1.1	3.3	806.8	240.738	0.080	0.074
BLACK	60.	1.713	0.1523	2.163	0.2497	1.3	2.8	572.8	210.406	0.091	0.055
SPANISH	30.	1.747	0.1456	2.117	0.2866	1.5	2.7	714.1	203.442	0.056	0.061
MALE	55.	1.749	0.1514	2.215	0.3039	1.1	3.0	691.5	223.719	0.078	0.059
FEMALE	57.	1.723	0.1464	2.168	0.3766	1.3	3.3	622.9	239.470	0.081	0.065
TOTAL	112.	1.736	0.1488	2.191	0.3421	1.1	3.3	656.6	233.381	0.079	0.062
GRADE 3											
OTHERS	13.	1.635	0.0853	2.618	0.5057	2.0	3.5	1299.5	391.565	0.078	0.040
BLACK	26.	1.638	0.1444	2.773	0.5111	1.6	3.6	1224.6	477.049	0.101	0.055
SPANISH	29.	1.634	0.1289	2.641	0.5039	2.1	3.9	1063.0	253.919	0.100	0.055
MALE	33.	1.639	0.1298	2.788	0.5128	2.1	3.9	1159.9	364.342	0.106	0.054
FEMALE	35.	1.633	0.1255	2.593	0.4839	1.6	3.6	1179.5	409.732	0.087	0.050
TOTAL	68.	1.636	0.1266	2.687	0.5041	1.6	3.9	1170.0	385.605	0.096	0.052
GRADE 4											
OTHERS	1.	1.930	0.0	3.600	0.0	3.6	3.6	981.0	0.0	0.170	0.0
BLACK	20.	1.801	0.1144	2.556	0.5747	1.7	3.7	699.3	199.635	0.114	0.079
SPANISH	12.	1.731	0.1583	2.988	0.8311	1.6	5.0	797.8	196.908	0.152	0.118
MALE	21.	1.749	0.1273	2.591	0.6383	1.6	3.7	765.6	183.626	0.104	0.075
FEMALE	12.	1.833	0.1371	3.014	0.7694	2.2	5.0	705.3	235.980	0.173	0.112
TOTAL	33.	1.780	0.1352	2.745	0.7077	1.6	5.0	743.7	202.688	0.129	0.094
GRADE 5											
BLACK	8.	1.862	0.0518	2.825	0.5523	2.4	4.1	1299.2	504.592	0.080	0.039
SPANISH	6.	1.817	0.0753	2.800	0.5762	2.2	3.6	1786.3	217.364	0.056	0.037
MALE	7.	1.857	0.0535	2.657	0.4577	2.2	3.6	1325.9	535.854	0.073	0.048
FEMALE	7.	1.829	0.0756	2.971	0.6047	2.2	4.1	1690.1	327.784	0.067	0.029
TOTAL	14.	1.843	0.0646	2.814	0.5405	2.2	4.1	1508.0	466.736	0.070	0.038
GRADE 6											
SPANISH	1.	1.900	0.0	5.100	0.0	5.1	5.1	995.0	0.0	0.322	0.0
FEMALE	1.	1.900	0.0	5.100	0.0	5.1	5.1	995.0	0.0	0.322	0.0
TOTAL	1.	1.900	0.0	5.100	0.0	5.1	5.1	995.0	0.0	0.322	0.0

Table 3-4 presents the rate of progress by grade and entry level for the three CAI curriculums: mathematics, reading, and language. Differences among the curriculums are immediately apparent. Rate of progress is lowest in reading and highest in language. In the reading curriculum only the first two entries in grade 4 and the last three in grade 6 are above .100. In the language curriculum none of the entries are below .100 and 13 of the 27 entries are above .200. Rates in the mathematics curriculum are intermediate--between the two extremes. Perhaps this is what the conventional wisdom of CAI coordinators was expressing. It was easy to get through the language curriculum, harder to get through the mathematics curriculum, and hardest (or slowest) to get through the reading curriculum. From the data one is unable to determine whether it is the difficulty of items, the underlying software or some other reason that makes progress in the reading curriculum so slow.

Summary

In this chapter we have seen graphs of students' progress in each of the three CAI curriculums. We have seen that for a given range of entry level scores--1.5 to 1.9 in the mathematics CAI curriculum--there were students from all six grade levels proceeding through the curriculum at varying rates. We have observed that the rate of progress is highest in the language curriculum, intermediate in the mathematics curriculum, and slowest in the reading curriculum. The data agree with observations from coordinators in the CAI labs.

Table 3-4

Rate of Progress by Grade and Entry Level for Three CAI Curriculums: MATHEMATICS, READING AND LANGUAGE.

MATHEMATICS GRADE	1.0-1.4	1.5-1.9	2.0-2.4	2.5-2.9	3.0-3.4	3.5-3.9	4.0-4.4	4.5-4.9	5.0-5.4	5.5-5.9	6.0-6.4	6.5-6.9	7.0-7.4	7.5-7.9
1	.086	.075	.076											
2	.101	.079	.087	.122	.169	.154								
3	.095	.096	.099	.116	.130	.161	.230							
4	.130	.129	.114	.123	.143	.142	.097							
5		.070	.079	.092	.106	.109	.126	.127	.108	.125	.113			
6		.322	.126	.141	.130	.115	.164	.188	.173	.116	.107	.079		
READING GRADE														
1														
2														
3														
4				.130	.102	.068	.073	.065	.068	.072	.016	.051		
5				.061	.083	.086	.064	.075	.081	.062	.067	.086		
6				.077	.069	.065	.065	.057	.064	.246	.122	.112		
LANGUAGE GRADE														
1														
2														
3					.156	.188	.198	.176	.320					
4					.212	.264	.236	.296	.175		.137			
5					.234	.223	.170	.254	.186	.161	.267	.230		
6					.226	.163	.184	.161	.164	.166	.280	.259		

Chapter V

CONCLUSIONS

Part 3 of the final report has described briefly the three curriculums used in our longitudinal study of CAI. The curriculums were found to adapt readily to the entry level abilities of most students. The mathematics strands curriculum had the broadest capability. Students in grade 4, for example, were placed across all grade levels by the initial rapid motion phase of the curriculum, and regular progress in the curriculum was fast enough to keep students motivated.

Reading and language CAI curriculums were less adaptable to students' entry level abilities. Some fourth grade students topped out of the language curriculum, while others had difficulty moving beyond the lowest level of the reading curriculum. Progress in the language curriculum was fast enough to keep students motivated, but progress in reading was much slower.

We also took a careful look at students' time on CAI in order to determine that the research design requirements were met. Although there was considerable variation in the amount of time on CAI for individuals, times for different CAI treatment groups were remarkably alike. We also found that students assigned to varying levels of CAI did, in fact, receive varying levels of treatment. We turn now to Part 4 of the final report and an examination of the effectiveness of the CAI curriculums.

PART 4*

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

THE EFFECTIVENESS OF CAI

*This appeared as Part 4 of M. Ragosta, P. W. Holland, and D. T. Jamison Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. Final Report to the U. S. National Institute of Education, April 1982.

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OVERVIEW

In part 4 of the Final Report we turn to studies of the effectiveness of the CCC curriculums as used in CAI labs in four elementary schools in the Los Angeles Unified School District. Part 4 of the Final Report is organized in the following manner:

- In Chapter I the research design is presented.
- In Chapter II a discussion of the research methodology will present the underlying statistical model. The explication of a specific analysis is used to illustrate the basic procedures. Finally, there is a short section on how to read the tables used to report the treatment effects.
- In Chapter III 12 one-year studies of CAI are summarized by grade level. Only within-CAI analyses--the randomized parts of the research design--are reported.
- In Chapter IV each of the three longitudinal studies is summarized. Within-CAI analyses are presented first but analyses based on cohort controls and comparison-school students are included.
- In Chapter V the big picture is presented. Treatment effects in mathematics, reading and language arts are estimated in terms of standard deviations. These estimates are made first for the one-year within-CAI studies, then for the longitudinal within-CAI studies, and finally for the cohort-control and comparison-school studies.
- In Chapter VI we summarize our findings and present our conclusions.

Before we turn to the effectiveness data, however, let us consider what it is that we are studying. We are estimating the effectiveness of several CAI curriculums produced by Computer Curriculum Corporation and used in CAI labs as a pull-out program for drill-and-practice in mathematics, reading, and language arts. There are many versions of CAI; the one we are studying represented the broadest programmatic approach at the time of this project's funding.

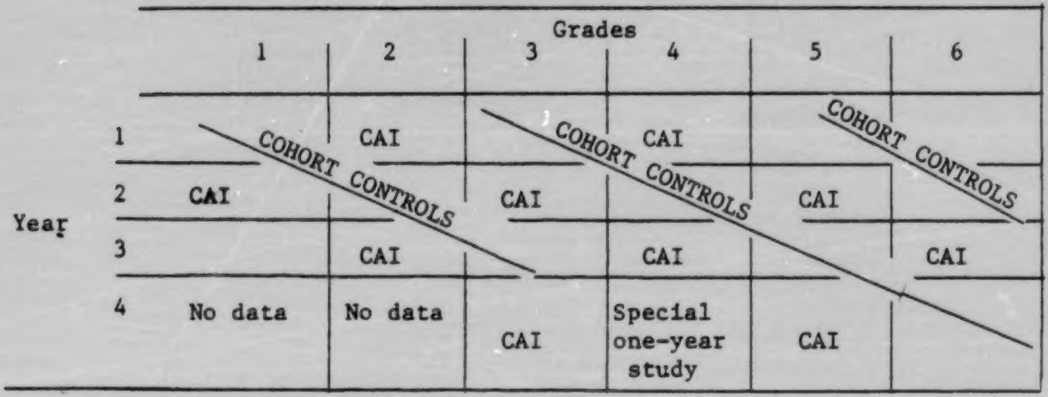
Chapter I

THE RESEARCH DESIGN

The research design determined which students would--or would not--receive computer-assisted instruction during each of the four years of the study. It further determined which of the CAI curriculums, or combination of curriculums, a student would receive. It also provided for three kinds of control groups.

Six schools in Los Angeles participated in the study: four as schools with CAI labs and two as comparison schools. Students in the two comparison schools provided one kind of control group. The advantage of the comparison group was that data could be collected simultaneously for CAI students at a particular grade level and students at the same grade level in comparison schools. At the end of any year of data collection, CAI students could be directly compared to comparison-school students. There were obvious disadvantages to using comparison schools: differences in populations of students, leadership styles of principals, teachers and teaching practices, and the overall school environment. Better control groups were provided from within the CAI schools.

Approximately half of the students in the four CAI schools received computer-assisted instruction while half did not.



Year	Grades 1	2	3	4	5	6
1		CAI		CAI		
2	CAI		CAI		CAI	
3		CAI		CAI		CAI
4	No data	No data	CAI	Special one-year study	CAI	

Students in grades 2, 4 and 6 were assigned CAI in year 1; their cohorts in grades 1, 3 and 5 were not. In year 2, first graders were assigned CAI along with third and fifth graders who continued to receive it. In year 3, CAI was limited to students in grades 2, 4 and 6. In year 4, CAI was continued for students in grades 3 and 5 and a special one-year study of CAI was conducted in grade 4. Students in grades where CAI was not assigned became the second kind of control group--the cohort controls. One advantage of the cohort control group was that the population of students and the school environment (principals, teachers, school practices, etc.) were similar to those of the CAI students. The disadvantage was that data at any grade level was collected a year earlier or later than data for CAI students. At the end of year 1, for example, no cohort-control data was available for grades 2, 4 and 6 where students were receiving CAI. Only after the second year of data collection was completed could CAI students be compared with their cohort controls.

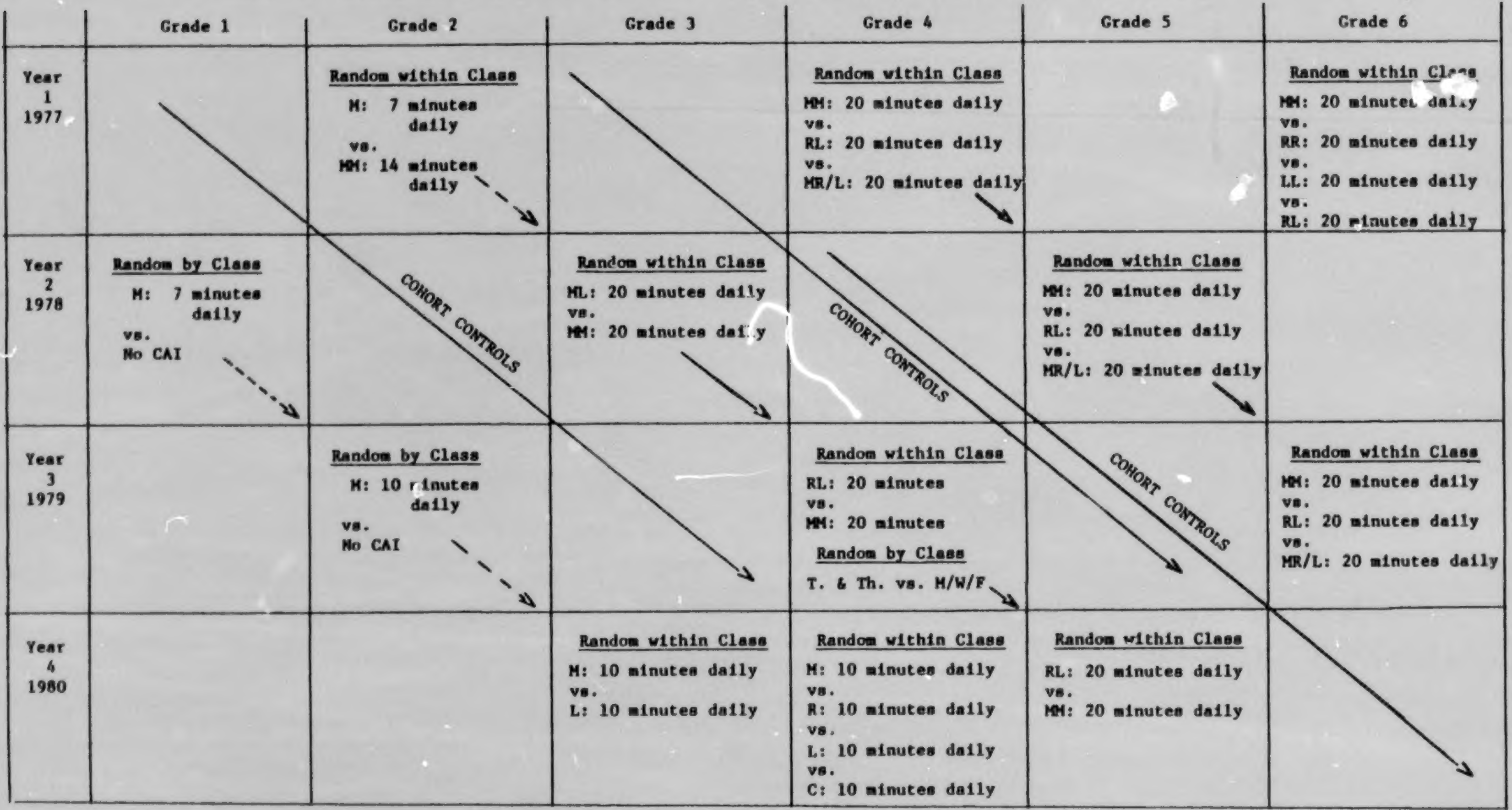
The comparison of CAI students with their cohort controls is a test of CAI used as a substitute for part of a teacher's classroom time.

The best control groups were provided within the ranks of students receiving computer-assisted instruction. These control groups were achieved by random assignment of students to their CAI curriculums, thus creating the conditions for a genuine social experiment. Twelve one-year studies of CAI were designed to evaluate the effectiveness of the CAI curriculums over one year or longer periods of time. The twelve one-year studies are outlined in Figure 4-1.

In year 1, sixth-grade students were randomly assigned within classrooms to receive either: two session of mathematics (MM), two sessions of reading (RR), two sessions of language (LL), or one session of reading and one of language (RL). The MM students served as a control group for those CAI students receiving reading and/or language and, conversely, the RR, LL and RL groups served as controls for students receiving mathematics CAI.

Similarly, students in grade 4 in year 1 were randomly assigned to receive either: two sessions of mathematics (MM), one session of reading and one of language (RL), or one session of mathematics with one session where reading and language alternate (MRL). Students' assignments in grade 4 were continued into grades 5 and 6, and new students were randomly assigned as they entered the system. The MM group served as a control for two levels of CAI reading and language assignments (RL and MRL), and the RL group served as a control for two levels of mathematics CAI (MM and MRL).

(NOTE: M = Mathematics CAI, R = Reading CAI, L = Language CAI, C = Reading for Comprehension CAI)



	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Year 1 1977		Random within Class M: 7 minutes daily vs. MM: 14 minutes daily		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily		Random within Class MM: 20 minutes daily vs. RR: 20 minutes daily vs. LL: 20 minutes daily vs. RL: 20 minutes daily
Year 2 1978	Random by Class M: 7 minutes daily vs. No CAI		Random within Class ML: 20 minutes daily vs. MM: 20 minutes daily		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily	
Year 3 1979		Random by Class M: 10 minutes daily vs. No CAI		Random within Class RL: 20 minutes vs. MM: 20 minutes Random by Class T. & Th. vs. M/W/F		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily
Year 4 1980			Random within Class M: 10 minutes daily vs. L: 10 minutes daily	Random within Class M: 10 minutes daily vs. R: 10 minutes daily vs. L: 10 minutes daily vs. C: 10 minutes daily	Random within Class RL: 20 minutes daily vs. MM: 20 minutes daily	

Figure 4-1 CAI Treatment Over 4 Years

Students in grade 2 in year 1 were randomly assigned within classrooms to either one or two sessions of mathematics CAI. This was the only design which created opposition on the part of teachers and students and it was never repeated. When the students became third-graders, they were reassigned to receive either two sessions of mathematics CAI daily (MM) or one session of mathematics and one of language (ML). The simpler vocabulary and faster movement of the language CAI curriculum were the reasons for its selection over the reading curriculum for this grade level. In subsequent years, the ML students received reading and language CAI (the RL group) while the MM group continued to receive two sessions of mathematics. In the three-year longitudinal study--and the two two-year studies--which resulted from the use of CAI in grades 3-5, the MM group served as controls for the ML-RL-RL group and the latter served as controls for the MM group.

For the first-grade students who became part of the CAI study in year 2, random assignments within classrooms could not be made to different curriculums because only mathematics CAI was available in grades 1 and 2. Random assignments to different levels of mathematics CAI were not made within classrooms because of the disruption caused by that design in year 1. First-grade classrooms were first paired on the basis of student-ability and/or other variables, and then one member of the pair was randomly assigned to CAI while the other served as a control. The same procedure was used subsequently in grade 2. By the end of grade 2 there were 4 kinds of CAI conditions among the students: some had received two years of mathematics CAI, some had received CAI only in grade 1, some had received CAI only in grade 2, and some had received no CAI at all. In grade 3 in the final year of the study, all students were randomly assigned within classrooms to receive either one session of mathematics or one session of language. In the three-year longitudinal study including students in grades 1-3, controls were provided by levels of use of the mathematics CAI curriculum: for zero, one, two, or 3 years.

In the special one-year study at fourth grade in the final year, students were randomly assigned to one 10-minute CAI session daily of either mathematics (M), reading (R), language (L) or a newer curriculum (available at one school only) reading-for-comprehension (C). In this study each group served as a control for the others.

As part of the research design, all students were pretested and posttested each year of the study with standardized achievement tests; generally, Iowa Tests of Basic Skills in the fall (September/October) and the Comprehensive Tests of Basic Skills in the spring (April/May).

	PRETEST	POSTTEST
GRADE 1	CTBS Form S Level A	CTBS Form S Level B
2	ITBS Form 5 Level 7	CTBS Form S Level C
3	ITBS Form 5 Level 8	CTBS Form S Level 1
4	ITBS Form 5 Level 9	CTBS Form S Level 1
5	ITBS Form 5 Level 10	CTBS Form S Level 2
6	ITBS Form 5 Level 11	CTBS Form S Level 2

Except for the fall of year 1, all students were also pretested and posttested each year with curriculum-specific tests (CSTs) developed for the study from the CAI curriculums. Both the standardized tests and CSTs are relevant and reasonable instruments for measuring treatment effects but they may be viewed as providing two kinds of information: the former give a general treatment effect which may be compared with treatment effects in other studies using standardized tests; the CSTs give what may be considered the upper boundary of the treatment effect. Whereas the treatment effects arising from the standarized tests might be depressed due to a mismatch between the CAI curriculum and the test, the treatment effects using the CSTs might be overinflated because control groups were not exposed to the CAI material in the classroom.

Chapter II

RESEARCH METHODOLOGY

Our basic summary measures of the effectiveness of the various CAI curriculums studied in this investigation are estimated treatment effects that have been adjusted for pretest scores and a variety of other variables. In this section we shall give a careful description of the regression methodology that was used to obtain these estimates throughout the many subanalyses that make up this report. We shall concentrate here on a specific analysis that we will call the Basic Analysis. The Basic Analysis formed the prototype for all of the analyses of achievement data in this report. Specific subanalyses required certain modifications of the Basic Analysis, and these modifications are described in the sections that give the subanalysis results.

The Underlying Statistical Model

In all of the analyses reported here, we are interested in the relative effects of exposure (and non-exposure) to various CAI curriculums on student outcomes as measured by certain tests. These test scores are the dependent variables in our analysis. We shall denote a generic dependent variable by the symbol Y, as is customary. However, we will depart somewhat from the usual regression notation because we wish to emphasize that, in an experiment like the present one, there are several versions of the dependent variable. There is a version for each potential exposure condition. For example, in grade 4 year 1 there were three possible combinations of CAI curriculums to which a student could be assigned. These were denoted MM, MRL or RL, respectively. Hence for each student in the experiment and for each Y there are potentially three different versions of Y that we could measure -- denoted Y_{MM}, Y_{MRL} or Y_{RL}.

The value of Y_{MM} is the value of Y that would be observed if the student were exposed to MM. The value of Y_{MRL} is the value of Y that would be observed if the same student were exposed to MRL. Similarly for Y_{RL}. If the CAI curriculums differ in their relative effectiveness, then for each student the values Y_{MM}, Y_{MRL} and Y_{RL} would not be expected to be the same. For example, if Y denotes the score on a mathematics test, then we would expect that $Y_{MM} \geq Y_{MRL} \geq Y_{RL}$ for each student in the experiment, since this ordering is the same as the order of the amount of exposure to the CAI Math curriculum. However, it is impossible to observe more than one of these three versions of Y for each student in the type of experiment we are discussing. Hence, the only information that we have available for a given subject and a given dependent variable Y is

$$(Y_S, S, X), \tag{1}$$

where S denotes the CAI (or non-CAI) condition to which the student was exposed, Y_S denotes the corresponding version of the dependent variable and X denotes a vector of covariates which are either measured prior to the exposure to the CAI curriculum (e.g., pretest scores) or not affected by it (e.g., gender or ethnicity). Since X is not affected by S, it does not have several versions in the way that Y does.

We can not directly compare the values of Y_{MM} and Y_{RL} for each student, but we can estimate the average value of Y_{MM} and of Y_{RL} in a given population of students and compare these averages. Our ability to estimate these averages depends on two things -- random assignment of students to curriculums and the use of covariates. We had one or both of these factors available to us throughout the entire study.

Let us denote the operation of taking a population average of a variable Y by the notation $E(Y)$, (or by $E_P(Y)$ if it is necessary to be explicit about the population, P). It is also necessary for us to have a notation for conditional population averages, that is averages of the values of one variable among only those students with a given value of another variable. We use the standard notation $E(Y|X)$ to denote the conditional average of Y for each fixed value of X. We will make use of the following fundamental equation that relates population averages and conditional population averages:

$$E(Y) = E\{E(Y|X)\}. \qquad (2)$$

The content of formula (2) is very simple -- the population average of Y can be computed by first averaging Y for each fixed value of X and then averaging these conditional averages using the proper weights that come from the distribution of X in the population.

The population treatment effect (T.E.) of an exposure condition, say MM, relative to a second exposure condition, say RL, is the average of the $Y_{MM} - Y_{RL}$ differences over the population, i.e.

$$T.E. = E(Y_{MM} - Y_{RL}). \qquad (3)$$

However, as we said earlier, since we can not compute $Y_{MM} - Y_{RL}$ for any single student, the treatment effect in (3) must be estimated via indirect means. The first step along this path is to use the fact that the "average of a sum is the sum of the averages" to obtain the equation

$$T.E. = E(Y_{MM}) - E(Y_{RL}) = E(Y_{MM} - Y_{RL}). \qquad (4)$$

Therefore the problem of estimating the treatment effect in (3) has been reduced to estimating the two means $E(Y_{MM})$ and $E(Y_{RL})$ over the population of students.

Before going on to show how one estimates $E(Y_{MM})$ and $E(Y_{RL})$ we briefly discuss our choices of treatment and control comparisons.

We often have more than two CAI exposure conditions in the substudies of this report. When this happens there is no unique way to define the treatment effects. We have adopted the convention of taking one of the exposure conditions as a control and computing all of the treatment effects relative to it. For the grade 4 year 1 example this means that when the dependent variable is a math test the treatment effects to be estimated are

$$E(Y_{MM} - Y_{RL}) = E(Y_{MM}) - E(Y_{RL}) \tag{5}$$

and

$$E(Y_{MRL} - Y_{RL}) = E(Y_{MRL}) - E(Y_{RL}). \tag{6}$$

These effects are meaningful in the context of this study because the amount of exposure to the CAI math curriculum is 0 for RL, 10 minutes per day for MRL and 20 minutes per day for MM. Hence we would expect the effect in (5) to exceed the one in (6).

For reading and language dependent variables, a different set of treatment effects are relevant. These are

$$E(Y_{RL} - Y_{MM}) = E(Y_{RL}) - E(Y_{MM}) \tag{7}$$

and

$$E(Y_{MRL} - Y_{MM}) = E(Y_{MRL}) - E(Y_{MM}). \tag{8}$$

Our general rule for choosing treatment effects is to use as the control the exposure condition with the lowest amount of exposure to the curriculum tested by the dependent variable. Thus, all of the treatment effects in this study are interpretable as the average number of test items correctly answered due to the increase in exposure to a specific CAI curriculum. We now return to our discussion of the estimation of the treatment effects.

It is one thing to set as a goal the estimation of the treatment effects given in (5)-(8), but quite another to design a study capable of doing that. Critical to our ability to estimate these treatment effects are two key features of the present study -- randomization and the availability of covariates. We discuss the role of these features now.

When we can only observe (Y_S, S, X) for each student as defined in (2), where X is the vector of covariates, S the exposure condition to which the student is exposed and Y_S the value of either Y_{MM}, Y_{MRL} or Y_{RL} (depending on the value of S), it is not directly possible to estimate $E(Y_{MM})$, $E(Y_{MRL})$ and $E(Y_{RL})$. For example, suppose we computed the average value of Y_{MM} for all those students exposed to MM (i.e., for whom S = MM). This is an estimate of

$$E(Y_{MM} | S = MM) \tag{9}$$

and not an estimate of $E(Y_{MM})$. The relationship between $E(Y_{MM})$ and $E(Y_{MM} | S = MM)$ can be expressed as

$$\begin{aligned} E(Y_{MM}) = {} & E(Y_{MM} | S = MM)\ P(S = MM) \\ & + E(Y_{MM} | S \neq MM)\ P(S \neq MM). \end{aligned} \tag{10}$$

Hence we see that in order to use the data that are collected to estimate the parameter of interest, a study must be designed to allow us to make reasonable assumptions about certain quantities or parameters that are inherently inestimable. In (10) the inestimable parameter is

$$E(Y_{MM} | S \neq MM) \tag{11}$$

which is the average value of Y_{MM} for those students in the population exposed to some CAI curriculum other than MM. Since we can only observe Y_{MM} for students exposed to MM, the quantity in (11) can not be estimated directly. This does not mean that the quantity in (11) is meaningless.

For example, in a randomized study, the assignment of students to curriculums is designed to be statistically independent of any dependent variable. A mathematical consequence of this statistical independence is that

$$E(Y_{MM}|S \neq MM) = E(Y_{MM}|S = MM). \tag{12}$$

Equation (12) says that the average value of Y_{MM} is the same for those students assigned to MM and those assigned to the other curriculums. If equation (12) is applied to (10) we obtain the following basic fact about a randomized experiment:

$$E(Y_{MM}) = E(Y_{MM}|S = MM). \tag{13}$$

The left side of equation (13) is the parameter we *wish* to estimate while the right side of (13) is the parameter we *can* estimate. Randomization makes them equal.

A second device that helps us towards our goal of estimating $E(Y_{MM})$, $E(Y_{MRL})$, etc. is the use of the covariates, X, which appear in (1). The covariates used in this study are pretest scores and certain demographic characteristics -- gender and ethnicity. The regression of Y_{MM} on X for the students exposed to MM is an estimate of the conditional population average of Y_{MM} given the value of X and S = MM. This is represented mathematically by

$$E(Y_{MM}|S = MM, X). \tag{14}$$

There is an equation that relates the regression function in (14) to the quantity that we are interested in estimating, i.e. $E(Y_{MM})$. This equation is like the equation in (10). It is

$$\begin{aligned} E(Y_{MM}) = {} & E\{E(Y_{MM}|S = MM, X)\ P(S = MM|X)\} \\ & + E\{E(Y_{MM}|S \neq M, X)\ P(S \neq MM)X)\}. \end{aligned} \tag{15}$$

Again, we see that the relation between $E(Y_{MM})$ and the regression function that we can estimate involves an inherently inestimable quantity. This time the inestimable quantity is

$$E(Y_{MM}|S \neq MM, X) \tag{16}$$

which is the regression of Y_{MM} on X for those students exposed to a curriculum other than MM.

If X predicts Y_{MM} well, (i.e., has a high R^2 value) or if S is independent of Y_{MM} because of randomization, we are often willing to assume that the regression function in (16) equals the one in (14). When this is true (15) reduces to

$$E(Y_{MM}) = E\{E(Y_{MM}|S = MM, X)\}. \tag{17}$$

Formula (17) does not assume that the regression function of Y_{MM} on X is linear, but for simplicity we will. If (14) is a linear regression then it is of the form

$$E(Y_{MM}|S = MM, X) = a + b\ X \tag{18}$$

where a is a scalar and b is a vector compatible with X. We have

$$E(Y_{MM}) = a + b\ E(X). \tag{19}$$

Equation (19) gives a formula for $E(Y_{MM})$ in terms of the regression of Y_{MM} on X for the group exposed to MM, and the average of X over the population. Correspondingly, if we can assume that

$$E(Y_{RL}|S \neq RL, X) = E(Y_{RL}|S = RL, X) = a^* + b^*\ X \tag{20}$$

then we have

$$E(Y_{RL}) = a^* + b^*\ E(X). \tag{21}$$

The treatment effect of MM relative to RL is then

$$T.E. = E(Y_{MM}) - E(Y_{RL}) = a-a^* +(b-b^*)\ E(X). \tag{22}$$

A special simplification occurs when the regressions in (19) and (21) are "parallel," i.e., when $b = b^*$. In this case the treatment effect reduces to

$$\text{T.E.} = a - a^* \tag{23}$$

which is the difference in intercepts for the two regressions.

Equation (23) is the basis for the way in which we performed the analysis in this study. We may summarize the assumptions that lead to it as follows:

(A1) Conditional independence of Y_{MM} and S given X,

$$E(Y_{MM}|S = MM, X) = E(Y_{MM}|S \neq MM, X).$$

(Similarly for the other exposure conditions, MRL and RL.)

(A2) Linear regressions, e.g.

$$E(Y_{MM}|S = MM, X) = a + b\, X.$$

(A3) Parallel regressions, e.g. the regressions of Y_{MM}, Y_{MRL} and Y_{RL} on X all have the same slopes, but may have different intercepts.

Assumptions (A2) and (A3) can be and were checked on the data for their adequacy. Assumption (A1) can be insured by the use of randomization and/or the use of covariates which are well correlated with the dependent variables.

The Basic Analysis

We now discuss the specific analysis used in grade 4, year 1 of the study. This is the Basic Analysis referred to earlier and forms the prototype for all of the other analyses performed in this part of the report.

There were three CAI curriculums available in grade 4 -- mathematics (M), reading (R) and language (L). Students were assigned randomly to one of three CAI curriculum combinations in grade 4, year 1. These are denoted MM, MRL and RL:

MM = Two, 10-minute sessions of mathematics CAI per day.

RL = One, 10-minute session each of reading CAI and language CAI per day (total of 20 minutes per day).

MRL = One, 10-minute session of mathematics CAI per day and one, 10-minute session of either reading CAI or language CAI (alternating weekly) per day (total of 20 minutes per day).

The assignment of students to the treatment conditions was random within classrooms. Thus, each classroom may be viewed as a separate population, P_i, in the analysis. However, the sample sizes at the classroom level are quite small, and it is customary in such circumstances to "pool" the analysis across the classrooms. By "pooling" we do not mean simply treating all the classrooms together as one big sample in which we ignore the classroom a student comes from. Instead we "pool by parallel regressions". This is done as follows. In the $i^{\underline{th}}$ classroom, P_i, the mean of Y_{MM} is denoted $E_{P_i}(Y_{MM})$. Equation (19) should then be written to show the dependence of the regression coefficients on i, i.e.

$$E_{P_i}(Y_{MM}) = a_i + b_i\ E(X). \qquad (24)$$

Similarly, for equation (21). Under assumptions (A1), (A2) and (A3).

the treatment effect of MM relative to RL in classroom P_i is $a_i - a_i^*$. When we pool by parallel regressions we assume that the treatment effects in each classroom are equal, i.e. that

$$a_i - a_i^* = \tau_{MM} \tag{25}$$

for each i. We also assume that the slopes b_i in all the classrooms are equal. A corresponding assumption is made regarding the treatment effects of MRL relative to RL. These assumptions in conjunction with (A1), (A2), and (A3) lead to these three parallel regression equations:

$$\begin{aligned} E_{P_i}(Y_{MM}|S = MM, X) &= a_i^* + \tau_{MM} + b\,X \\ E_{P_i}(Y_{MRL}|S = MRL, X) &= a_i^* + \tau_{MRL} + b\,X \\ E_{P_i}(Y_{RL}|S = RL, X) &= a_i^* + b\,X \end{aligned} \tag{26}$$

These regression equations are estimated all at once by a single regression analysis which fits the following model:

$$\begin{aligned} \hat{Y} = a &+ \sum_i c_i CL_i + dMALE + \sum_j e_j ETH_j \\ &+ \sum_k b_k PRT_k + \tau_{MM} MM + \tau_{MRL} MRL. \end{aligned} \tag{27}$$

In (27) CL_i is an indicator (zero/one) variable for students in P_i ($CL_i = 1$ for students in P_i); MALE is an indicator variable for gender (MALE = 1 for males); ETH_j is an indicator variable for the j^{th} ethnic category; PRT_k is the value of the k^{th} pretest score used in the analysis as a covariate; MM is a treatment indicator for students assigned to MM. Similarly for MRL.

The identification of the regression parameters in the three equations in (26) with the estimated coefficients in (27) is as follows:

$a_i^* = a + c_i$ for all but the last classroom,

$a_{LAST}^* = a$

$b = (d, e_1, e_2, \ldots, b_1, b_2, \ldots)$

τ_{MM} and τ_{MRL} in (26) correspond exactly to the quantities with the same labels in (27).

Table 4-1 gives the estimated values for the coefficients in (27) and their associated t-values for the dependent variable, Y = Total Score on fourth grade Math CST. From the values in Table 4-1 we can form the three estimated regression equations from (26) that correspond to each classroom. For example, for the first classroom (i.e., CLASS 107) the three equations are:

$$20.52 + 14.51 - 1.36\ MALE - 10.73\ ETH_1 - 3.45\ ETH_2 + 0.87\ PRT_1 + 1.56\ PRT_2$$

$$20.52 + 5.25 - 1.36\ MALE - 10.73\ ETH_1 - 3.45\ ETH_2 + 0.87\ PRT_1 + 1.56\ PRT_2$$

$$20.52 - 1.36\ MALE - 10.73\ ETH_1 - 3.45\ ETH_2 + 0.87\ PRT_1 + 1.56\ PRT_2.$$

These three estimated regression equations are the result of a pooled regression and, as such, are not the equations that would be obtained if a separate analysis were made of the three treatment groups in the first classroom. The results of the pooled regression are preferred when the samples in each treatment group in each class are small, because they are more accurate than the results of separate

Table 4-1

Example showing the results of a pooled regression analysis to estimate treatment effects for grade 4 year 1.

Dependent variable = CST Math Total.

Variable Name in Formula (27)	Coefficient in Formula (27)	Variable Name in Regression Output	Estimated Coefficient	t-value
-	a	PSEUDO	32.11	4.18
CL_1	c_1	CLASS107	-11.59	-1.55
CL_2	c_2	CLASS108	6.38	0.87
CL_3	c_3	CLASS216	-10.50	-1.52
CL_4	c_4	CLASS218	-4.30	-0.55
CL_5	c_5	CLASS301	-5.86	-0.96
CL_6	c_6	CLASS308	-7.27	-1.09
CL_7	c_7	CLASS322	-10.79	-1.80
CL_8	c_8	CLASS329	-17.65	-2.92
CL_9	c_9	CLASS414	-4.57	-0.76
MALE	d	MALE	-1.36	-0.53
ETH_1	e_1	BLACK	-10.73	-1.99
ETH_2	e_2	SPANISH	-3.45	-0.71
PRT_1	b_1	4M1..RW1	0.87	2.65
PRT_2	b_2	4M2..RW1	1.56	3.67
MM	τ_{MM}	MM	14.51	4.52
MRL	τ_{MRL}	MRL	5.25	1.73

N = 175, $R^2 = 0.580$, Std. err. reg. = 16.12

analyses. For example, the first classroom contains 18 students distributed into the three CAI exposure conditions, whereas the regression results in Table 4-1 are based on 175 students from 10 classrooms.

When using pooled regression analyses as we do throughout this report, it is necessary to make certain checks on the fit of the estimated equation to insure that the benefits of the pooling are not lost because of an increase in bias in the estimates. We made these checks by routinely testing for interactions between the treatment indicator variables and the other independent variables in the regression analysis. In almost all cases we found no significant interactions that would lead us to change our method of estimating the treatment effects.

The Format of the Tables used to Report Estimated Treatment Effects

We have adopted a consistent format for displaying the estimated treatment effects for all of the substudies discussed in this part of the report. In order to help the reader understand the relevant information in these tables we give here a brief description of the example in Table 4-2.

The heading indicates what type of substudy is described by the table -- a one-year analysis, a longitudinal analysis or a comparison of CAI with non-CAI students, either cohort controls or comparison-school controls. The heading also gives the grade level and year or years of the study, as well as the type of test(s) used as the dependent variable (CTBS or CST) and the subject area. Each table refers to a single subject area (mathematics, reading or language) as the dependent variable.

The body of the table is divided into columns for (a) the name of the sub-tests, (b) the treatment group, (c) the N's for the treatment group, (d) the estimated treatment effects, (e) their associated t-statistics, (f) the posttest means for each treatment group, (g) the posttest standard deviation in each treatment group and (h) the residual standard deviations from the regression analysis used to estimate the treatment effects, and (i) the standardized treatment effect.

The rows of the table are grouped according to the subtests and the total for the given tested subject area described by the table. Each of these groups of rows consists of a single row for each experimental group in the analysis.

The treatment effect for the "control" in each analysis is zero by definition and this is indicated by a dash (-) in Table 4-2 for RL students. The treatment effects for the experimental conditions can be interpreted as mean numbers of correct items. The MM group on Subtest A answered 9.29 more questions correctly--on the average--than did RL students, adjusting for covariates. The degrees of freedom for the t-statistic are the same for each subtest of the CST or CTBS and are given in the heading. The "residual S.D." is defined as the square root of the error mean square from the regression analysis. The standardized treatment effect in the last column is the treatment effect divided by the residual standard deviation and can be interpreted as a treatment effect in terms of standard deviations. Interpretation of the standardized treatment effect derives from norms for the rate of achievement growth per month of typical schooling. At most elementary school grades the difference between the average student at the beginning and end of the same grade is about 1.00 standard deviations. One month in school accounts on the average for a growth of 0.10 standard deviation units. In Table 4-2, the treatment effect for the MM group on Subtest A when divided by the residual S.D. indicates that MM students' adjusted mean scores are about one standard deviation higher than adjusted mean scores for RL students. (9.29/9.38 = .99) This metric--the standardized treatment effect--is used whenever treatment effects are to be averaged across studies.

Table 4-2

One-Year Analysis for GRADE = 4 YEAR = 1.

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-6.

CST	Treatment Group	N	Treatment Effect	(t) 158df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	52	9.29	4.98	35.94	14.65	9.38	0.99
	MRL	66	3.06	1.73	29.76	10.33		0.33
	RL	57	-		27.35	11.79		-
PART B	MM	52	5.23	3.25	23.92	12.39	8.08	0.65
	MRL	66	2.19	1.44	20.29	10.33		0.27
	RL	57	-		18.75	9.80		-
MATH TOTAL	MM	52	14.51	4.52	59.86	25.44	16.12	0.99
	MRL	66	5.25	1.73	50.04	23.04		0.33
	RL	57	-		46.10	20.41		-

CTBS	Treatment Group	N	Treatment Effect	(t) 180df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	63	-0.11	-0.07	35.57	11.18	8.14	-0.01
	MRL	67	-2.19	-1.48	33.16	11.11		-0.27
	RL	68	-		35.71	10.57		-
CONCEPTS	MM	63	-1.24	-1.81	15.90	6.47	3.73	-0.33
	MRL	67	-0.95	-1.40	15.94	5.48		-0.25
	RL	68	-		17.44	5.53		-
APPLICATIONS	MM	63	-1.00	-1.25	13.33	7.16	4.36	-0.23
	MRL	67	-1.35	-1.71	12.79	6.60		-0.31
	RL	68	-		15.09	6.29		-
MATH TOTAL	MM	63	-2.34	-1.01	64.60	22.16	12.69	-0.18
	MRL	67	-4.50	-1.95	61.90	20.82		-0.35
	RL	68	-		68.24	20.64		-

The Roles of CSTs and CTBS

The roles of the CSTs and the CTBS, when used as dependent variables in our analyses, are viewed by us as somewhat different. The subtests in both sets of tests are relevant and reasonable instruments for measuring student performance in their respective areas. However, because the CSTs were constructed deliberately from the items in the CCC curriculums, their main role in our analyses is to measure the extent to which each of the CAI curriculums altered the students' performance on the material *used in each CAI curriculum*. In other words, the CSTs *are* curriculum specific and are aimed at measuring whether or not each CAI curriculum was successful in improving the performance of the students on the material in which it was drilling them.

The CTBS, on the other hand, is the standardized test used by the LAUSD for measuring student progress from all types of schooling experience -- not merely CAI experience. It is a measure that is not directly tied to the CCC curriculum. Student improvement on the CTBS that is due to exposure to a CAI condition in our experiment can be used to estimate the effect of these CAI curriculums on standardized test scores more generally.

Chapter III

ONE-YEAR EXPERIMENTAL STUDIES

In this section of the report we examine the effectiveness of the CAI curriculums. For each of the one-year studies in the research design, we will summarize the result by grade level. Furthermore, in this chapter we will examine only the within-CAI experimental comparisons. When we restricted intervention to within-CAI comparisons, then most students in the several samples had about the same length of exposure per year to at least one CAI curriculum. In Table 4-3 all the one-year studies are tabulated, and the CAI exposure conditions summarized. Some one-year studies were designed to measure the one-year effect of CAI and some were a part of a longitudinal study which was designed to assess the long-term effect of CAI exposure.

All the students in the study, regardless of which of the six schools they were in and whether or not they were exposed to one or more CAI curriculum, took a pretest of either the ITBS or CTBS (depending on the grade level) and, after the first year, a curriculum-specific test (CST) before the onset of the CAI each fall. They were also administered both the CTBS and the CST posttests in the spring. Other information such as sex and ethnicity for each student was also obtained. The information collected in the study is summarized in Part 2 of this report together with a description of the overall design of the study.

The basic regression analysis used to estimate treatment effects is similar for all the one-year studies. It is described in Part 4, Chapter II. The purpose of the regression analysis is to estimate the CAI treatment effects relative to a particular control group after adjusting for all

Table 4-3

CAI Treatment Over 4 Years

(NOTE: M = Mathematics CAI, R = Reading CAI, L = Language CAI, C = Reading for Comprehension CAI)

	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Year 1 1977		Random within Class M: 7 minutes daily vs. MM: 14 minutes daily		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily		Random within Class MM: 20 minutes daily vs. RR: 20 minutes daily vs. LL: 20 minutes daily vs. RL: 20 minutes daily
Year 2 1978	Random by Class M: 7 minutes daily vs. No CAI		Random within Class ML: 20 minutes daily vs. MM: 20 minutes daily		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily	
Year 3 1979		Random by Class M: 10 minutes daily vs. No CAI		Random within Class RL: 20 minutes vs. MM: 20 minutes Random by Class T. & Th. vs. M/W/F		Random within Class MM: 20 minutes daily vs. RL: 20 minutes daily vs. MR/L: 20 minutes daily
Year 4 1980			Random within Class M: 10 minutes daily vs. L: 10 minutes daily	Random within Class M: 10 minutes daily vs. R: 10 minutes daily vs. L: 10 minutes daily vs. C: 10 minutes daily	Random within Class RL: 20 minutes daily vs. MM: 20 minutes daily	

the pretests and demographic differences. The choice of specific control groups depends on the particular dependent variable being examined. As we indicated in part 4, section II, our general rule was to use as the control the CAI treatment with the least exposure to the curriculum tested by the given variable.

For each of the six grade levels, we will first summarize the studies and the CAI curriculums compared over the four years. Even though the original research plan called for complete randomization wherever possible, some deviation from complete randomization did occur for numerous reasons. For this reason we feel it is very important that covariance adjusted treatment effects be the basic measure of effectiveness used in the study. Depending on the grade level and class structure, some restrictions on the level of randomization were implemented. We will briefly describe the experimental designs along with the regression analyses used for these designs for each one-year study for a given grade level. Discussions of the results are followed by tables summarizing all the treatment effects from the regression analyses, as well as the posttest means by treatment group.

The Grade 1 Study

The Design of the Experiment in Grade 1, Year 2

In the first grade the only available CCC CAI curriculum is mathematics. Primarily because of this, the assignment to CAI mathematics curriculum in grade 1, year 2 was on a classroom-by-classroom basis. Thus an entire classroom of first graders either went to the CAI room for 10 minutes a day or never went there. The assignment of classrooms to CAI was done randomly. Thus, the randomization is within the school but not within each classroom. The random assignment also restricted pairs of classrooms in the same school, if possible, to achieve balance between treatment. Because the CAI assignment was not completely random by students, classroom differences are not controlled for CAI treatment effect as they are in most of the other one year studies where assignment could be randomized within class.

Regression analyses were run using all students who had both pretest and posttest data. The covariates were CST math subscores and CTBS math raw scores. Indicator variables for sex, ethnicity, and school were also used to adjust the CAI treatment effect.

Results for Grade 1, Year 2

Table 4-4 gives the results for grade 1, year 2 for CST and CTBS mathematics scores. The treatment effect for the CST mathematics total is statistically significant. Students with mathematics CAI answered 16 more questions correctly, on the average, than did students without CAI. The two parts of the CST contributed about equally to the total treatment effect. For CTBS mathematics scores, the treatment effect for mathematics total is positive but not significant for the students with CAI. Both subtest scores are also positive, but only the concepts and applications subtest achieved statistical significance.

Table 4-4

One-Year Analysis for GRADE = 1 YEAR = 2.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 119df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART_A	M	49	8.50	6.34	30.14	9.71	7.13	1.19
	O	74	-		23.39	13.20		-
PART B	M	49	7.94	4.95	25.47	11.10	8.54	0.93
	O	74	-		18.93	13.17		-
MATH TOTAL	M	49	16.44	6.18	55.61	19.18	14.15	1.16
	O	74	-		42.32	25.77		-

CTBS	Treatment Group	N	Treatment Effect	(t) 119df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	M	52	0.72	0.64	16.19	8.19	6.22	0.12
	O	78	-		15.99	8.02		-
CONCEPTS AND APPLICATIONS	M	52	1.32	2.06	14.23	4.08	3.54	0.37
	O	78	-		13.50	5.53		-
MATH TOTAL	M	52	2.04	1.39	30.42	11.08	8.13	0.25
	O	78	-		29.49	12.31		-

The Grade 2 Studies

For grade 2, the only curriculum available was mathematics as in grade 1. Two different studies were conducted in years 1 and 3 to provide within-CAI comparisons. The situation for grade 2 across the four years of the study is summarized as follows:

	Year 1	Year 2	Year 3	Year 4
Grade 2	CAI: MM, M	Cohort Controls	CAI:M (F vs. V) and Controls	- -
	Comparisons	Comparisons	Comparisons	-

The Design and Analyses of the Two Grade 2 Studies

The two levels of treatment which were assigned at grade 2 in year 1 were one session of mathematics every day (M) and two sessions of mathematics every day (MM). Second graders were randomly assigned to the treatment conditions within classrooms in the first year of the study. Students in mixed classes (either 1-2 or 2-3) were assigned to MM for the convenience of the teachers. This design was chosen to measure the effects of different amounts of exposure to the CAI mathematics curriculum for grade 2 students. The within-classroom randomization to different amounts of the same CAI curriculum was difficult to implement for various practical reasons.

The longer period of CAI time for the MM group gave teachers an opportunity to work with students remaining in the classroom; the shorter period of time for the M group did not. These treatment conditions were not received well by teachers and were not repeated again in the study after year 1.

In year 3, the choice of curriculum in grade 2 was again restricted to math, but instead of random assignment within classroom, students were assigned randomly by classroom as they had been in grade 1. In addition, within each classroom assigned to receive mathematics CAI, the students were randomly divided into those to receive the "fixed" strands method of delivery of the curriculum or the "variable" strands method of delivery. In all other instances in the study, mathematics variable strands were used. In variable strands questions from each of the available strands are delivered to students in variable order. In fixed strands, one can amend the usual procedure and concentrate on one specific strand--e.g., vertical addition--and receive 10 minutes of drill and practice in that strand only. Students assigned to fixed strands received fixed strands for only part of their CAI lab time, usually Tuesdays and Thursdays, while receiving variable strands during the rest of their lab time. Teachers were permitted to select the fixed-mathematics assignments for their students. When teachers did not wish to make the selection, CAI coordinators did so, usually by assigning fixed strands in whichever of the various strands the student's placement was lowest.

Results for Grade 2

Year 1. In the first year of the study the CAI labs were opened in February. The CSTs were administered in June after 3-1/2 months of CAI, but the CTBSs were administered in April after only 6-8 weeks of CAI.

Table 4-5 gives the results for the CST and CTBS mathematics scores. The treatment effects for the total CST and the part scores are not statistically significant. Students who received 2 sessions of CAI in the second grade did only marginally better than students taking one session.

For the CTBS mathematics scores, the treatment effect for the mathematics total is statistically significant as are the treatment effects for both computation and concepts and applications. Students who received two sessions of math for the 6-8 weeks prior to CTBS testing performed better than students receiving one session.

Table 4-5

One-Year Analysis for GRADE = 2 YEAR = 1.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 197df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	155	0.49	0.34	34.87	12.23		0.06
	M	65	-		33.98	12.98	8.30	-
PART B	MM	155	0.68	0.48	22.14	12.81		0.08
	M	65	-		23.74	13.13	8.06	-
MATH TOTAL	MM	155	1.17	0.47	57.01	23.69		0.08
	M	65	-		57.72	24.91	14.32	-

CTBS	Treatment Group	N	Treatment Effect	(t) 207df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	164	1.55	2.07	15.24	6.91		0.35
	M	66	-		15.11	6.96	4.46	-
CONCEPTS AND APPLICATIONS	MM	164	1.14	1.98	15.20	5.23		0.33
	M	66	-		14.76	5.36	3.43	-
MATH TOTAL	MM	164	2.69	2.38	30.44	11.36		
	M	66	-		29.87	11.65		

Year 3. We shall first look at the results of a comparison of CAI students with students who did not receive CAI. Table 4-6 shows the results for the CST and CTBS mathematics scores. Treatment effects for the CST total score and the part scores are all statistically significant. Students with CAI answered 12 more questions correctly on the average than did students without CAI. Expressed in proportions of the residual standard deviation, the adjusted mean for the CST mathematics total for CAI students is .79 of a standard deviation above the adjusted mean of non-CAI students.

For the CTBS mathematics scores, the treatment effects for the total and the subtests are all statistically significant. The CAI students correctly answered 2.55 more computation questions and 1.08 more application questions than did students without CAI. Expressed in a proportion of the residual standard deviation, the adjusted mean for CTBS mathematics computation for CAI students is .51 of a standard deviation above the adjusted mean of non-CAI students.

Table 4-6

One-Year Analysis for GRADE = 2   YEAR = 3.

Posttest = CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 189df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	M	100	5.72	4.44	39.07	9.91	8.75	0.65
	O	99	-		31.39	12.48		-
PART B	M	100	6.37	5.21	27.29	12.88	8.30	0.77
	O	99	-		18.14	11.42		-
MATH TOTAL	M	100	12.08	5.35	66.36	21.36	15.34	0.79
	O	99	-		49.54	22.72		-

CTBS	Treatment Group	N	Treatment Effect	(t) 196 df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	M	104	2.55	3.37	18.31	6.29	5.03	0.51
	O	102	-		14.26	6.90		-
CONCEPTS AND APPLICATIONS	M	104	1.08	2.10	16.29	4.78	3.43	0.31
	O	102	-		13.71	5.38		-
MATH TOTAL	M	104	3.62	3.41	34.60	10.11	7.08	0.51
	O	102	-		27.96	11.20		-

Students in second-grade classrooms assigned to CAI in Year 3 were randomly assigned to receive--or not receive--part of their instruction in the fixed-strands mode. Ordinarily students receiving mathematics CAI took it in the variable mode; i.e., questions from all available components of the mathematics curriculum appeared in random sequence. A question on measurement might be followed by one on vertical addition followed by one on horizontal subtraction. In the fixed-strand mode, students were assigned for part of their CAI time to a specific strand--e.g., horizontal addition selected by the teacher.

Table 4-7 shows the results for the CST and CTBS mathematics scores. None of the treatment effects is statistically significant, although there appears to be a trend favoring students who took part of their instruction in fixed strands.

Table 4-7

One-Year Analysis for GRADE = 2 YEAR = 3.

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	90df.	$\bar{X}$	SD	SD	T.E.
PART A	M-VARIABLE	52	-2.80	-1.62	38.00	11.25	8.00	-0.35
	M-FIXED	48	-		40.23	8.05		-
PART B	M-VARIABLE	52	0.11	0.07	28.14	13.59	8.01	-0.01
	M-FIXED	48	-		26.38	11.99		-
MATH TOTAL	M-VARIABLE	52	-2.69	-0.91	66.14	23.32	14.37	-0.19
	M-FIXED	48	-		66.61	19.00		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	94df	$\bar{X}$	SD	SD	T.E.
COMPUTATION	M-VARIABLE	55	-0.37	-0.39	17.91	6.88	4.56	-0.08
	M-FIXED	49	-		18.76	5.52		-
CONCEPTS AND APPLICATION	M-VARIABLE	55	-0.91	-1.44	15.73	4.89	3.03	-0.30
	M-FIXED	49	-		16.92	4.58		-
MATH TOTAL	M-VARIABLE	55	-1.27	-0.95	33.64	10.68	6.45	-0.20
	M-FIXED	49	-		35.67	9.30		-

Summary of Grade 2 Data

In only one case were CAI students compared with non-CAI students in grade 2. In year 3, second-grade students who received mathematics CAI performed significantly better than students without CAI.

When students were assigned to one or two sessions of mathematics CAI, those with two sessions performed significantly better on the CTBS mathematics subtests than those assigned to one session.

Where students were assigned fixed strands for part of their CAI lab time, no statistically significant differences in treatment effects occur, although the trend seems to favor the fixed-strand group.

The Grade 3 Studies

The third-grade studies and curriculums compared are summarized as follows:

	Year 1	Year 2	Year 3	Year 4
Grade 3	Cohort Controls	CAI: MM, ML	Cohort Controls	CAI: M, L
	Comparisons	Comparisons	Comparisons	-

For grade 3, CAI curriculums were administered in year 2 and year 4. The other two years provided the cohort controls and comparison school controls which are discussed later in the report.

The Design of the Experiment in Grade 3, Year 2 and Year 4

In the third grade, two CAI curriculums were available--mathematics and language. In year 2, students were randomly assigned within classrooms either to 20 minutes of mathematics CAI a day (MM) or to 10 minutes of mathematics and 10 minutes of language CAI (ML). At that time, the language curriculum was not more extensively utilized because of the uncertainties as to whether or not it could be used by students in grade 3. It turned out that 10 minutes a day of CAI language curriculum could be implemented in a satisfactory way in grade 3. With this experience, in year 4 students were randomly assigned to 10 minutes of mathematics a day (M) or 10 minutes of language a day (L). This design gives us direct comparison between the mathematics curriculum and the language curriculum. In both designs students were assigned to either treatment on a student-by-student basis rather than a class-by-class basis. Thus, in a typical third-grade CAI class, there will be approximately equal numbers of students in either condition.

Results for Grade 3

Year 2. Table 4-8 gives the results for grade 3, year 2 for CST and CTBS mathematics scores. The treatment effects for the CST total and part scores are statistically significant. Students who received 2 sessions of mathematics CAI daily performed significantly better on the mathematics CST than students assigned to mathematics and language CAI. In terms of the residual standard deviation, the adjusted means of the MM students are about two-thirds of a standard deviation higher than the adjusted means of ML students on the CST total mathematics score.

Only one of the CTBS subtests shows statistically significant treatment effects. Students assigned MM did significantly better on mathematics computation than did students assigned to ML. The MM students are about one-third of a standard deviation better than the ML students on mathematics computation.

Table 4-8

One-Year Analysis for GRADE = 3 YEAR = 2.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 173df.	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	111	4.56	3.15	44.22	11.74	9.20	0.50
	ML	80	-		39.80	14.31		-
PART B	MM	111	5.60	4.69	34.94	12.33	7.60	0.74
	ML	80	-		29.21	13.70		-
MATH TOTAL	MM	111	10.16	4.29	79.15	22.91	15.07	0.67
	ML	80	-		69.01	26.73		-

CTBS	Treatment Group	N	Treatment Effect	(t) 186df.	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	113	2.80	2.44	30.50	11.16		0.38
	ML	91	-		28.01	11.63	7.44	-
CONCEPTS	MM	113	-0.14	-0.22	12.79	6.47		-0.03
	ML	91	-		12.91	6.51	4.04	-
APPLICATIONS	MM	113	0.15	0.23	10.82	6.34		0.04
	ML	91	-		11.09	6.52	4.17	-
MATH TOTAL	MM	113	2.81	1.47	54.11	21.51		0.23
	M	91	-		52.01	22.89	12.35	-

Table 4-9

One-Year Analysis for GRADE = 3 YEAR = 2.

Posttest= CST Subject = READING AND LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

Subtest	Treatment Group	N	Treatment Effect	(t) 175df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
READING	MM	115	-		36.65	15.40	10.65	-
	ML	78	-1.64	0.98	36.83	15.31		-0.15
LANGUAGE	MM	115	-		31.51	13.73	8.70	-
	ML	78	3.96	2.90	37.09	13.21		0.46
TOTAL	MM	115	-		68.16	27.37	17.35	-
	ML	78	2.32	0.85	73.92	26.99		0.13

Tables 4-9 and 4-10 present the reading and language results for the CST and CTBS tests. The CST results reported in Table 4-9 are based on a reading test and a language test. It was not expected a priori that ML students would perform better on the reading portion of the CST, but their performance on the language portion of the test was expected to be better. Although the results for reading are not significant, the results for language are statistically significant. Students assigned to ML answered, on the average, four more questions correctly than MM students. The adjusted mean score for ML students on the language CST is .46 of a standard deviation higher than the adjusted mean score for MM students.

For the CTBS data, none of the treatment effects is statistically significant.

Table 4-10

One-Year Analysis for GRADE = 3 YEAR = 2.

Posttest = CTBS Subject = READING AND LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CTBS READING	Treatment Group	N	Treatment Effect	(t) 180df.	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	111	-		16.65	8.81	3.75	-
	ML	89	-0.59	-1.02	16.36	8.97		-0.16
COMPREHENSION	MM	111	-		18.28	10.22	5.35	-
	ML	89	-1.56	-1.89	17.20	11.26		-0.29
READING TOTAL	MM	111	-		34.94	18.48	7.77	-
	ML	89	-2.15	-1.79	33.56	19.60		-0.28

CTBS LANGUAGE	Treatment Group	N	Treatment Effect	(t) 179df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	111	-		25.51	8.35		-
	ML	88	-0.75	-0.77	25.02	8.47	6.28	-0.12
MECHANICS	MM	111	-		8.56	4.40		-
	ML	88	0.26	0.66	9.28	4.68	2.58	0.10
EXPRESSION	MM	111	-		13.54	7.35		-
	ML	88	0.02	0.04	13.77	7.45	3.34	0.01
LANGUAGE TOTAL	MM	111	-		47.61	17.84		-
	ML	88	-0.46	-0.34	48.08	18.57	8.87	0.05

Year 4. Table 4-11 presents the results for grade 3, year 4 CST and CTBS mathematics tests. The treatment effects for the CST total and part scores are all statistically significant. Students assigned to mathematics CAI completed an average of 12.78 more questions correctly than students assigned to language CAI. The adjusted mean score for the M group is .82 of a standard deviation higher than the adjusted mean score for the L group.

None of the CTBS tests demonstrate significant treatment effects. Results of the CTBS computation test, with a treatment effect of 2.09 items, approaches significance.

Table 4-11

One-Year Analysis for GRADE = 3 YEAR = 4.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 188df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	M	124	6.97	5.04	42.39	11.71	8.89	0.78
	L	82	-		37.83	14.77		-
PART B	M	124.	5.80	4.45	29.50	13.54	8.40	0.69
	L	82	-		26.97	13.15		-
MATH TOTAL	M	124	12.78	5.30	71.89	24.05	15.52	0.82
	L	82	-		64.80	26.85		-

CTBS	Treatment Group	N	Treatment Effect	(t) 148df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	M	90	2.09	1.80	30.09	11.39	6.95	0.30
	L	77	-		28.22	11.31		-
CONCEPTS	M	90	-0.67	-1.23	13.61	5.76	3.28	-0.20
	L	77	-		14.34	5.97		-
APPLICATIONS	M	90	0.06	0.10	11.55	5.98	3.86	0.02
	L	77	-		11.44	6.31		-
MATH TOTAL	M	90	1.47	0.81	55.25	21.19	10.91	0.13
	L	77	-		54.00	21.65		-

Tables 4-12 and 4-13 present the reading and language results for grade 3, year 4. Results for the reading and language CST scores look similar to those reported for grade 3, year 2. No significant effect appears for the reading portion of the CST, but a statistically significant effect shows up for the language portion. The adjusted mean for the language students is .41 of a standard deviation higher than the adjusted mean for students in the mathematics CAI curriculum.

For the CTBS reading and language scores (Table 4-13), statistically significant treatment effects are found for vocabulary, reading total, spelling and language total. For those four test scores the adjusted means for language CAI students are one-third to one-half of a standard deviation higher than the adjusted means for mathematics CAI students.

Table 4-12

One-Year Analysis for GRADE = 3 YEAR = 4.

Posttest= CST Subject = READING AND LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

Subtest	Treatment Group	N	Treatment Effect	(t) 156df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
READING	M	93	-		40.40	15.69	11.90	-
	L	82	1.80	0.95	44.56	14.44		0.15
LANGUAGE	M	93	-		37.41	12.71	9.40	-
	L	82	3.90	2.61	42.86	12.68		0.41
TOTAL	M	93	-		77.81	27.06	19.70	-
	L	82	5.70	1.82.	87.39	25.87		0.30

Table 4-13

One-Year Analysis for GRADE = 3 YEAR = 4.

Posttest= CTBS Subject = READING AND LANGUAGE.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CTBS READING	Treatment Group	N	Treatment Effect	(t) 155df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	M	93	-		16.99	8.43	4.81	-
	L	82	1.64	2.15	20.15	8.91		0.34
COMPREHENSION	M	93	-		18.35	10.75	5.88	-
	L	82	1.59	1.70	21.57	10.84		0.27
READING	M	93	-		35.34	18.44	9.42	-
TOTAL	L	82	3.23	2.16	41.72	19.13		0.34

CTBS LANGUAGE	Treatment Group	N	Treatment Effect	(t) 155df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	M	93	-		25.34	8.53	5.20	-
	L	82	2.64	3.20	29.76	7.98		0.51
LANGUAGE	M	93	-		9.35	4.15	2.92	-
MECHANICS	L	82	0.90	1.92	10.94	5.01		0.31
LANGUAGE	M	93	-		14.54	6.61	4.05	-
EXPRESSION	L	82	0.50	0.78	16.18	6.85		0.12
LANGUAGE	M	93	-		49.24	16.89	8.67	-
TOTAL	L	82	4.04	2.93	56.88	17.73		0.47

Summary of the Grade 3 Data

Overall, students in grade 3 who received mathematics CAI performed significantly better on mathematics CSTs and on CTBS computation subtests than students receiving language. Conversely, those students assigned to the language CAI curriculum performed significantly better on the language portion of the CST. The CTBS language results differ from year 2 to year 4. In year 2 the treatment effects for the spelling subtest and language total are both negative; in year 4 they are both positive and both statistically significant.

The Grade 4 Studies

The one-year studies for grade 4 and curriculums compared are summarized as follows:

	Year 1	Year 2	Year 3	Year 4
Grade 4	CAI: MM, MRL, RL	Cohort Controls	CAI: MM, RL	CAI: M,R,L,C
	Comparisons	Comparisons	Comparisons	-

Because two longitudinal studies span fourth grade and a special study occurred in year 4, we have three studies of CAI for grade 4.

The Design and Analyses for Grade 4

In year 1, all fourth-grade students were given two 10-minute sessions on the computer with three different combinations. The three CAI curriculum combinations are MM (two sessions of math) RL (one session of reading and one session of language), and MR/L (one session of math followed by one session of reading or language alternatively). Students were randomly assigned to one of the three treatment curriculums. Comparisons across treatments represent the randomized part of the research design. There are three levels of math treatments: students in MM are the high math group; students in MRL are the low math group; and students in RL are the zero math group. Similarly, there are three levels of the R and L curriculums with RL representing the high group, MRL the low, and MM the zero condition.

We made the assumption (based on a lack of evidence) that the Reading and Language CAI curriculums were not mutually exclusive, i.e., they covered much of the same material in a similar format. Therefore, equal time was given to math skills and verbal skills.

The design gave us a randomized comparison among three levels of math and verbal curriculum.

In year 3, the students could be classified into two groups according to their experience with CAI. Because of the LAUSD desegregation plan, there were six classrooms of students in grade 4 at School 1. Most of these students were new to CAI. The grade 4 students in the other three CAI schools had been in the CAI program for two previous years. The two curriculums available were MM, which represented two sessions of 10 minutes of math, and RL, which represented one session of reading and one session of language. Within each classroom, students who were new to CAI were randomly assigned to either MM or RL. Students who were previously in CAI would receive the same curriculum as they received in year 2. This was a section of the grade 2 to grade 5 longitudinal study. Because the small CAI lab at School 1 could not cope with that many students--about 150--on a daily basis, the grade 4 classrooms were assigned randomly to the CAI lab either on Monday, Wednesday and Friday (MWF), or Tuesday and Thursday (T/Th). Students in the MWF group were to have twenty more minutes CAI than those in T/Th group weekly.

In year 4, the one-year study for grade 4 was designed to determine the separate contributions of four CAI curriculums: mathematics (M), language (L), reading (R), and a new reading for comprehension (C) curriculum. In

School 1, approximately 150 fourth-grade students were randomly assigned to M, R or C. In the other CAI schools fourth-grade students were randomly assigned to M,R, or L. All students were new to CAI and went to the CAI lab for 10 minutes of CAI daily from mid-October to the end of May. This was the first time fourth-grade students received CAI on a daily basis over the whole academic year. This study was designed to measure specifically the one-year treatment effect. Students in School 1 took mathematics, reading, and comprehension CST posttests while students in other CAI schools had mathematics, reading and language CST posttests.

Results appear on the following pages.

Results for Grade 4

Year 1. Table 4-14 presents the mathematics results for fourth graders in year 1. For the CST data, the treatment effects for the MM group are all statistically significant and for the MRL group are all positive but not significant. The MM group is .9 of a standard deviation higher than the RL group on the CST mathematics total. For the CTBS data, all the treatment effects are negative, and those for the MRL group in computation and mathematics total are statistically significant.

Table 4-15 presents the reading results. For the CST reading total, the treatment effect for the RL group is statistically significant. The RL group is .47 of a standard deviation above the MM group on the CST reading total. For the CTBS data, there are statistically significant treatment effects for the RL group in reading vocabulary and reading total, with the performance of the RL group more than one-third of a standard deviation above that of the MM group.

Table 4-16 presents the language results for grade 4, year 1. For the CST language total, the treatment effects for both the RL and MRL groups are statistically significant, with the performance of the RL group more than a standard deviation above that of the MM group. For the CTBS data, statistically significant treatment effects are found for the RL group in spelling and language total.

Table 4-14

One-Year Analysis for GRADE = 4 YEAR = 1.

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-6.

	Treatment Group	N	Treatment Effect	(t) 158df.	Posttest		Residual SD	Standardized T.E.
CST					$\bar{X}$	SD		
PART A	MM	52	9.29	4.98	35.94	14.65	9.38	0.99
	MRL	66	3.06	1.73	29.76	10.33		0.33
	RL	57	-		27.35	11.79		-
PART B	MM	52	5.23	3.25	23.92	12.39	8.08	0.65
	MRL	66	2.19	1.44	20.29	10.33		0.27
	RL	57	-		18.75	9.80		-
MATH TOTAL	MM	52	14.51	4.52	59.86	25.44	16.12	0.99
	MRL	66	5.25	1.73	50.04	23.04		0.33
	RL	57	-		46.10	20.41		-

	Treatment Group	N	Treatment Effect	(t) 180df	Posttest		Residual SD	Standardized T.E.
CTBS					$\bar{X}$	SD		
COMPUTATION	MM	63	-0.11	-0.07	35.57	11.18	8.14	-0.01
	MRL	67	-2.19	-1.48	33.16	11.11		-0.27
	RL	68	-		35.71	10.57		-
CONCEPTS	MM	63	-1.24	-1.81	15.90	6.47	3.73	-0.33
	MRL	67	-0.95	-1.40	15.94	5.48		-0.25
	RL	68	-		17.44	5.53		-
APPLICATIONS	MM	63	-1.00	-1.25	13.33	7.16	4.36	-0.23
	MRL	67	-1.35	-1.71	12.79	6.60		-0.31
	RL	68	-		15.09	6.29		-
MATH TOTAL	MM	63	-2.34	-1.01	64.60	22.16	12.69	-0.18
	MRL	67	-4.50	-1.95	61.90	20.82		-0.35
	RL	68	-		68.24	20.64		-

Table 4-15

One-Year Analysis for GRADE = 4 YEAR = 1.

Posttest = CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-6.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	183df	$\bar{X}$	SD	SD	T.E.
PART A	MM	61	-		45.70	13.12	8.34	-
	MRL	76	1.98	1.35	47.59	9.78		0.24
	RL	68	4.28	2.75	51.85	5.31		0.51
PART B	MM	61	-		30.39	13.40	7.78	-
	MRL	76	-0.65	-0.48	29.62	11.84		-0.08
	RL	68	2.66	1.84	35.40	10.71		0.34
READING TOTAL	MM	61	-		76.10	25.32	14.73	-
	MRL	76	1.33	0.51	77.21	20.74		0.09
	RL	68	6.94	2.53	87.25	14.85		0.47

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	196df	$\bar{X}$	SD	SD	T.E.
VOCABULARY	MM	62	-		22.35	9.05	5.20	-
	MRL	70	0.23	0.24	21.96	8.72		0.04
	RL	73	1.43	1.53	24.27	9.28		0.28
COMPREHENSION	MM	62	-		25.18	19.89	7.01	-
	MRL	70	-0.28	-0.22	24.33	11.25		-0.04
	RL	73	1.59	1.27	27.62	11.50		0.23
READING TOTAL	MM	62	-		47.53	19.89	10.62	-
	MRL	70	-0.05	-0.03	46.29	18.98		0.00
	RL	73	3.02	1.58	51.89	19.42		0.28

Table 4-16

One-Year Analysis for GRADE = 4 YEAR = 1

Posttest = CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 183df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	61	-		39.68	11.99	7.00	-
	MRL	76	2.23	1.81	41.71	10.51		0.32
	RL	68	6.43	4.93	47.88	6.81		0.92
PART B	MM	61	-		34.44	12.09	7.23	-
	MRL	76	3.05	2.40	37.05	9.94		0.42
	RL	68	7.35	5.46	43.81	8.55		1.02
LANGUAGE TOTAL	MM	61	-		74.13	23.07	12.68	-
	MRL	76	5.28	2.37	78.76	19.21		0.42
	RL	68	13.77	5.83	91.96	14.27		1.09

CTBS	Treatment Group	N	Treatment Effect	(t) 196df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	62	-		28.71	9.73	6.71	-
	MRL	70	0.54	0.46	29.10	8.04		0.08
	RL	73	2.25	1.86	31.62	9.97		0.34
MECHANICS	MM	62	-		10.69	4.90	3.34	-
	MRL	70	-0.02	-0.03	10.66	4.86		-0.01
	RL	73	0.69	1.15	11.68	4.92		0.21
EXPRESSION	MM	62	-		16.98	7.42	4.65	-
	MRL	70	-0.34	-0.41	16.36	7.54		-0.07
	RL	73	0.98	1.18	18.30	7.97		0.21
LANGUAGE TOTAL	MM	62	-		56.39	19.04	11.24	-
	MRL	70	0.19	0.09	56.11	18.06		0.02
	RL	73	3.92	1.94	61.60	20.22		0.35

Year 3. Table 4-17 presents the mathematics results for fourth graders in Year 3. For the CST data, treatment effects for the MM group are all statistically significant. Performance of the MM group is almost two-thirds of a standard deviation above that of the RL group on the CST mathematics total. For the CTBS data, the only statistically significant treatment effect is for the MM group in mathematics computation.

Table 4-18 presents the reading results. For the CST reading total as well as part B, treatment effects for the RL group are statistically significant. Overall, performance of the RL group exceeds that of the MM group by one-third of a standard deviation. For the CTBS data, the RL group again out-performed the MM group with statistically significant treatment effects in comprehension and reading total.

Table 4-19 presents the language results. For the CST data, all treatment effects for the RL group are statistically significant, with the adjusted mean for the RL group about two-thirds of a standard deviation above that of the MM group. For the CTBS data, statistically significant treatment effects for the RL group occur for language mechanics, language expression and the language total. Overall, the adjusted mean for RL students on the CTBS language total is .28 of a standard deviation higher than that of the MM students.

Table 4-17

One-Year Analysis for GRADE = 4 YEAR = 3.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 256df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	RL	112	-		35.78	11.32	7.80	-
	MM	169	5.17	5.24	41.96	11.76		0.66
PART B	RL	112	-		24.89	10.42	7.24	-
	MM	169	3.24	3.54	29.19	13.45		0.45
MATH TOTAL	RL	112	-		60.67	20.64	13.51	-
	MM	169	8.41	4.92	71.15	24.26		0.63

CTBS	Treatment Group	N	Treatment Effect	(t) 252df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	MM	169	2.28	2.15	37.74	10.30	8.26	0.28
	RL	107	-		36.52	9.68		-
CONCEPTS	MM	169	0.23	0.45	16.95	5.95	3.94	0.06
	RL	107	-		17.72	5.61		-
APPLICATIONS	MM	169	0.41	0.78	14.64	6.78	4.17	0.10
	RL	107	-		15.06	7.06		-
MATH TOTAL	MM	169	2.92	1.73	69.34	20.22	13.14	0.22
	RL	107	-		69.30	19.80		-

Table 4-18

One-Year Analysis for GRADE = 4 YEAR = 3.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 240df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	161	-		50.07	9.47	6.85	-
	RL	106	1.17	1.38	52.11	6.32		0.17
PART B	MM	161	-		34.76	12.45	7.01	-
	RL	106	2.75	2.98	38.90	9.65		0.39
READING TOTAL	MM	161	-		84.83	20.42	11.61	-
	RL	106	3.92	2.57	91.02	14.96		0.34

CTBS	Treatment Group	N	Treatment Effect	(t) 245df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
VOCABULARY	MM	165	-		22.73	10.11		-
	RL	108	1.43	1.91	24.35	10.52	5.73	0.25
COMPREHENSION	MM	165	-		26.09	12.09		-
	RL	108	1.97	2.02	27.04	11.99	7.48	0.26
READING TOTAL	MM	165	-		48.82	21.28		-
	RL	108	3.40	2.22	51.39	21.32	11.71	0.29

Table 4-19

One-Year Analysis for GRADE = 4 YEAR = 3.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 240df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	161	-		43.89	9.75	6.08	-
	RL	106	2.75	3.43	48.16	6.71		0.45
PART B	MM	161	-		37.51	10.42	6.96	-
	RL	106	4.74	5.18	43.33	8.18		0.68
LANGUAGE TOTAL	MM	161	-		81.41	18.94	11.48	-
	RL	106	7.49	4.96	91.49	13.94		0.65

CTBS	Treatment Group	N	Treatment Effect	(t) 245df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	165	-		29.34	9.70		-
	RL	108	0.23	0.27	29.36	9.45	6.72	0.03
MECHANICS	MM	165	-		11.25	4.91		-
	RL	108	1.39	3.16	12.52	4.40	3.37	0.41
EXPRESSION	MM	165	-		17.90	7.48		-
	RL	108	1.57	2.49	19.20	6.62	4.83	0.33
LANGUAGE TOTAL	MM	165	-		58.50	19.94		-
	RL	108	3.20	2.11	61.08	18.11	11.62	0.28

Year 4. Table 4-20 presents the mathematics results for fourth graders in year 4. For the CST data, treatment effects for the mathematics CAI students are all statistically significant and about two-thirds of a standard deviation above the adjusted mean of students in other CAI curriculums. For the CTBS data, none of the treatment effects is statistically significant, although the treatment effect for the group in computation is quite strong.

Table 4-21 presents the reading results for fourth graders in year 4. Statistically significant treatment effects appear only for the R group, which received CAI reading. Although the treatment effects for the L (lauguage) and C (reading for comprehension) groups are both strongly positive when compared to the M group, none of them is statistically significant. For the CTBS data, all of the treatment effects for students receiving reading, language or reading-for-comprehension CAI are positive but not statistically significant. Table 4-22 shows reading results for the reading-for-comprehension CST, which was developed for use in School 1 only. The treatment effect for group C is statistically significant, and the adjusted mean for group C is .60 of a standard deviation above the adjusted mean for group M.

Table 4-23 presents the language results for grade 4, year 4. For the CST given only in Schools 2-4, treatment effects on the language total are statistically significant for both the language group and the reading group. Adjusted means for the L and R groups are .50 and .80 of a standard deviation above that of the group. On the CTBS, statistically significant treatment effects exist for the L group in spelling, mechanics and language total; for the R group in mechanics and language total; and for the C group in language expression. All the rest of the treatment effects for R and C are positive but not significant.

Table 4-20

One-Year Analysis for GRADE = 4 YEAR = 4

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 294df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	M	119	4.50	5.27	40.23	11.88	7.13	0.63
	R,L,C	202	-		37.45	11.06		-
PART B	M	119	4.13	5.07	27.75	12.60	6.81	0.61
	R,L,C	202	-		25.87	11.25		-
MATH TOTAL	M	119	8.62	5.75	67.97	23.65	12.54	0.69
	R,L,C	202	-		63.31	21.25		-

CTBS	Treatment Group	N	Treatment Effect	(t) 271df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	M	103	3.16	1.94	37.82	9.20	7.38	0.43
	R	103	0.05	0.03	36.00	9.81		0.01
	L	58	0.88	0.45	36.43	10.63		0.12
	C	36	-		39.00	8.52		-
CONCEPTS	M	103	0.27	0.32	17.12	5.72	4.00	0.07
	R	103	-0.21	-0.25	17.16	5.59		-0.05
	L	58	-1.62	-1.54	16.02	5.82		-0.41
	C	36	-		20.03	3.92		-
APPLICATIONS	M	103	0.20	0.19	13.77	6.93	4.91	0.04
	R	103	-0.05	-0.04	14.08	6.93		-0.01
	L	58	-0.15	-0.12	13.74	7.03		-0.03
	C	36	-		18.14	6.40		-
MATH TOTAL	M	103	3.63	1.25	68.70	19.46	13.22	0.27
	R	103	-0.22	-0.08	67.25	19.84		-0.02
	L	58	-0.89	-0.26	66.19	21.07		-0.07
	C	36	-		77.17	17.13		-

Table 4-21

One-Year Analysis for GRADE = 4 YEAR = 4.

Posttest = CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 267df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	M	101	-		47.81	11.38		-
	R	101	2.97	2.71	52.03	6.73	7.58	0.39
	L	62	1.16	0.88	47.45	11.79		0.15
	C	32	2.08	1.19	53.47	3.67		0.27
PART B	M	101	-		31.83	12.76		-
	R	101	3.49	3.12	37.13	10.82	7.71	0.45
	L	62	2.07	1.55	32.31	13.59		0.27
	C	32	2.90	1.63	40.91	9.03		0.38
READING TOTAL	M	101	-		79.64	21.91		-
	R	101	6.46	3.46	89.16	15.96	12.91	0.50
	L	62	3.23	1.44	79.76	24.25		0.25
	C	32	4.98	1.67	94.374	11.91		0.39

CTBS	Treatment Group	N	Treatment Effect	(t) 260df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	M	96	-		22.87	10.55	5.89	-
	R	101	1.55	1.77	23.77	9.58		0.26
	L	60	2.11	1.95	21.22	9.66		0.36
	C	36	1.26	0.95	29.14	7.77		0.21
COMPREHENSION	M	96	-		24.87	11.51	7.25	-
	R	101	1.34	1.24	25.46	11.74		0.18
	L	60	1.52	1.14	23.05	12.69		0.21
	C	36	2.14	1.32	31.39	10.68		0.30
READING TOTAL	M	96	-		47.74	20.74	11.18	-
	R	101	2.89	1.74	49.24	20.32		0.26
	L	60	3.63	1.76	44.27	21.25		0.32
	C	36	3.40	1.35	60.53	17.23		0.30

Table 4-22

One-Year Analysis for GRADE = 4 YEAR = 4.

Posttest = CST Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 2-4.

Subtest	Treatment Group	N	Treatment Effect	(t) 159df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	M	63	-		46.11	12.88		-
	R	59	3.77	2.27	51.15	7.67	8.70	0.43
	L	60	1.74	1.07	47.83	11.21		0.20
PART B	M	63	-		30.19	12.99		-
	R	59	3.83	2.35	35.42	11.84	8.55	0.45
	L	60	2.40	1.51	32.60	13.03		0.28
TOTAL	M	63	-		76.30	23.30		-
	R	59	7.59	2.74	86.58	17.96	14.57	0.52
	L	60	4.14	1.52	80.43	23.03		0.28

One-Year Analysis for GRADE = 4 YEAR = 4.

Posttest = CST Subject = READING FOR COMPREHENSION.

Treatment effects and posttest means by treatment group, School = 1. (School = 1).

Subtest	Treatment Group	N	Treatment Effect	(t) 92df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
READING FOR COMPREHENSION	M	33	-		43.94	14.32		-
	R	40	-0.48	-0.25	44.28	14.29		-0.06
	C	34	4.70	2.33	51.35	11.92	7.87	0.60

Table 4-23

One-Year Analysis for GRADE = 4 YEAR = 4.

Posttest = CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 159df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	M	63	-		38.44	13.05		-
	R	59	4.89	3.31	44.42	8.79	7.71	0.63
	L	60	5.45	3.80	43.77	11.47		0.71
PART B	M	63	-		33.68	11.88		-
	R	59	2.31	1.47	37.52	9.38	8.26	0.28
	L	60	6.14	3.99	39.13	12.95		0.74
LANGUAGE TOTAL	M	63	-		72.13	23.49		-
	R	59	7.17	2.61	81.95	16.97	14.41	0.50
	L	60	11.59	4.31	82.90	23.78		0.80

CTBS	Treatment Group	N	Treatment Effect	(t) 260df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	M	96	-		29.06	9.78	6.06	-
	R	101	1.54	1.71	29.93	9.47		0.25
	L	60	2.93	2.62	29.07	8.85		0.48
	C	36	1.00	0.73	32.83	8.40		0.17
MECHANICS	M	96	-		11.31	4.86	3.29	-
	R	101	1.07	2.18	12.20	4.63		0.33
	L	60	1.44	2.37	11.33	4.77		0.44
	C	36	1.10	1.48	14.00	4.31		0.33
EXPRESSION	M	96	-		29.06	9.78	4.40	-
	R	101	1.08	1.64	29.93	9.47		0.25
	L	60	0.88	1.08	29.07	8.85		0.20
	C	36	1.99	2.01	32.83	8.40		0.45
LANGUAGE TOTAL	M	96	-		58.85	20.09	10.58	-
	R	101	3.68	2.34	61.35	18.13		0.35
	L	60	5.24	2.69	57.17	18.40		0.50
	C	36	4.08	1.71	69.86	15.14		0.39

Summary of the Grade 4 Data

The data across 3 years of CAI are fairly consistent, with the exception of the mathematics CTBS data in year 1, in which all treatment effects are negative for MM and MRL students. The mathematics results in grade 4, year 1 are puzzling. Pretest scores on the ITBS Level 9 mathematics subtests were the highest in the study. Both subtests contained word problems which required reading as well as mathematical ability. The scores of bilingual students were especially high. Since the test was read to students in lower grade levels, perhaps in some cases the mathematics pretests were read in grade 4 in year 1.

Mathematics results in years 3 and 4 are more consistent with data from earlier grades. Mathematics CAI students in years 3 and 4 show consistently positive effects with statistically significant effects on the CSTs and the computation subtest of the CTBS.

The reading results are consistently positive except for the MRL group in year 1. The RL students in years 1 and 3 and the reading (R) students received roughly equivalent amounts of reading CAI before being tested on the reading CST. In all 3 years those students performed significantly better on the reading CST than did students assigned to mathematics CAI. They also performed better on the CTBS reading subtests. Although only one of the treatment effects on the CTBS is statistically significant, they are consistently positive with test scores above 1.24.

The language results are even stronger. All students receiving language CAI and/or reading CAI have CAI treatment effects on the language CST which are positive and statistically significant. Except for the

MRL group in year 1, all CTBS treatment effects are positive, and treatment effects on the CTBS language totals are statistically significant.

In light of the poor performance of MM students in year 1 after only 2 months of CAI, the performance of the RL group in year 1 is surprising. The reading and language curriculums demonstrated their treatment effects much more quickly than the MM group. Although the treatment effects on the CTBS after only two months of CAI failed to reach statistical significance, they closely parallel the results of students in years 3 and 4 where the effects are often statistically significant.

The Grade 5 Studies

The one-year studies for grade 5 and curriculums compared are summarized as follows:

	Year 1	Year 2	Year 3	Year 4
Grade 5	Cohort Controls	CAI: MM, MRL, RL	Cohort Controls	CAI: MM, RL
	Comparisons	Comparisons	Comparisons	Comparisons

The Design and Analyses for Grade 5

In grade 5 all three CAI curriculums were available--math, reading, and language. In year 2 the design for the fifth grade continued the exposure conditions started in year 1 for the fourth graders. Thus there are three conditions:

MM = two 10-minute sessions of mathematics daily,

RL = one 10-minute session of reading and one 10-minute session of language daily,

MRL = one 10-minute session of mathematics followed by one 10-minute session alternating between reading and language.

Fifth graders who had been randomly assigned to one of these three conditions in year 1 retained their assignments, and new fifth graders were randomly assigned to one of the three conditions.

In year 4, the design for the fifth graders continued the exposure conditions for the fourth graders in year 3. Students were randomly assigned to either MM, two 10-minute session of mathematics daily, or RL, one 10-minute session of reading and one 10-minute session of language daily. The MM curriculum concentrated on math skills while the RL curriculum concentrated on verbal skills. This provided a direct comparison of the effectiveness of each of these two types of curriculums.

Results for Grade 5

Year 2. Table 4-24 gives the results for the CST and CTBS mathematics scores for fifth graders in year 2. For the CST data, the treatment effects for the MM students are all statistically significant, while for the MRL students only one part-score fails to reach significance. Treatment effects for the MM condition are double the treatment effects of the MRL condition. In terms of the residual standard deviation, MM students are .78 of a standard deviation and MRL students .38 of a standard deviation above the adjusted mean of the RL group. Of the CTBS subtests, only computation shows a statistically significant treatment effect for the MM group. The MRL group has a treatment effect in computation about half the size of the effect for the MM group, but it fails to reach significance.

Table 4-25 gives the results for the CST and CTBS reading scores for fifth graders in year 2. None of the treatment effects in reading are statistically significant.

Table 4-26 presents the results for the CST and CTBS language scores for fifth graders in year 2. For the curriculum-specific tests, the MRL condition failed to produce any statistically significant treatment effects, although the RL conditions did. Students who received the RL treatment performed significantly better than MM students on the language CSTs. The adjusted mean score for RL students is .74 of a standard deviation above the adjusted mean for the MM group. On the CTBS tests, however, none of the treatment conditions produced significant treatment effects in language subtests.

Table 4-24

One-Year Analysis for GRADE = 5   YEAR = 2.

Posttest= CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 163df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	61	4.83	3.51	35.43	12.05	6.84	0.71
	MRL	64	2.10	1.62	28.91	10.05		0.31
	RL	56	-		27.87	10.05		-
PART B	MM	61	3.93	3.50	31.93	9.71	5.58	0.70
	MRL	64	2.18	2.06	27.28	10.04		0.39
	RL	56	-		25.78	8.22		-
MATH TOTAL	MM	61	8.75	3.86	67.36	21.15	11.27	0.78
	MRL	64	4.28	2.00	56.19	21.93		0.38
	RL	56	-		53.66	17.44		-

CTBS	Treatment Group	N	Treatment Effect	(t) 172df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	MM	60	2.33	2.00	28.08	9.26	6.24	0.37
	MRL	67	1.20	1.07	25.73	9.34		0.19
	RL	63	-		25.09	9.22		-
CONCEPT	MM	60	-0.07	-0.13	12.73	4.17	2.84	-0.02
	MRL	67	-0.78	-1.53	11.60	4.23		-0.27
	RL	63	-		12.68	4.30		-
APPLICATION	MM	60	-0.32	-0.47	10.30	5.52	3.60	-0.09
	MRL	67	0.13	0.20	10.13	4.88		0.04
	RL	63	-		10.32	5.19		-
MATH TOTAL	MM	60	1.95	1.10	51.12	16.56	9.47	0.21
	MRL	67	0.55	0.32	47.46	16.56		0.06
	RL	63	-		48.09	16.26		-

Table 4-25

One-Year Analysis for GRADE = 5 YEAR = 2.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 150df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	55	-		36.87	10.48	6.85	-
	MRL	63	-0.32	-0.23	35.67	11.34		-0.05
	RL	52	1.29	0.92	41.11	9.86		0.19
PART B	MM	55	-		32.03	12.16	7.29	-
	MRL	63	-0.89	-0.60	30.09	13.41		-0.12
	RL	52	1.48	0.99	37.27	11.08		0.20
READING TOTAL	MM	55	-		68.91	21.99	12.69	-
	MRL	63	-1.21	-0.47	65.76	23.65		-0.10
	RL	52	2.77	1.07	78.38	20.10		0.22

CTBS	Treatment Group	N	Treatment Effect	(t) 149df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	54	-		20.31	7.32	4.65	-
	MRL	61	0.13	0.14	19.74	8.95		0.03
	RL	56	-0.16	-0.16	21.69	8.53		-0.03
COMPREHENSION	MM	54	-		21.83	8.54	5.26	-
	MRL	61	-1.31	-1.27	20.28	9.99		-0.25
	RL	56	-0.49	-0.45	22.78	9.00		-0.09
READING TOTAL	MM	54	-		42.15	14.85	8.48	-
	MRL	61	-1.17	-0.71	40.16	18.30		-0.14
	RL	56	-0.64	-0.37	44.48	16.72		-0.08

Table 4-26

One-Year Analysis for GRADE = 5 YEAR = 2.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 150df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	55	-		39.20	10.55	6.31	-
	MRL	63	2.14	1.66	41.32	9.35		0.34
	RL	52	4.38	3.39	46.36	7.83		0.69
PART B	MM	55	-		37.12	8.22	6.22	-
	MRL	63	-0.48	-0.38	37.01	9.87		-0.08
	RL	52	3.36	2.64	43.33	8.41		0.54
LANGUAGE TOTAL	MM	55	-		76.33	17.42	10.52	-
	MRL	63	1.66	0.77	78.33	17.98		0.16
	RL	52	7.75	3.59	89.69	15.20		0.74

CTBS	Treatment Group	N	Treatment Effect	(t) 149df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	54	-		32.80	7.31	5.05	-
	MRL	61	-0.79	-0.80	32.28	9.21		-0.16
	RL	56	1.09	1.05	36.27	8.54		0.22
MECHANICS	MM	54	-		10.70	3.95	2.92	-
	MRL	61	0.48	0.84	11.05	4.86		0.16
	RL	56	0.47	0.78	11.84	3.93		0.16
EXPRESSION	MM	54	-		17.74	6.63	4.17	-
	MRL	61	-1.06	-1.30	16.34	6.91		-0.25
	RL	56	-1.59	-1.86	17.36	6.98		-0.38
LANGUAGE TOTAL	MM	54	-		61.24	15.55	8.73	-
	MRL	61	-1.37	-0.80	59.67	18.96		-0.16
	RL	56	-0.04	-0.02	65.46	17.17		0.00

Year 4. Table 4-27 presents the results for CST and CTBS mathematics tests for fifth graders in year 4. For the CSTs, the treatment effects for the MM group are all statistically significant. The adjusted mean for the CST total for the MM group is .76 of a standard deviation above the adjusted mean for the RL group. For the CTBS data, only the treatment effect for computation is statistically significant and favors the MM group by half a standard deviation.

Table 4-28 presents the results for CST and CTBS reading scores for fifth graders in year 4. Again, there are no statistically significant treatment effects although all are positive. The reading total for the CTBS approaches significance, with the adjusted mean score for the RL group about one-third of a standard deviation higher than the adjusted mean for the MM group.

Table 4-29 presents the results for CST and CTBS language tests for fifth graders in year 4. For the CSTs, the treatment effects for the RL group are all statistically significant with the performance of the RL group about one-half a standard deviation above the performance of the MM group. Although the treatment effects on the CSTs are positive overall for the RL group, none of them achieves statistical significance.

Summary of the Grade 5 Data

The results for grade 5 in years 2 and 4 are remarkably similar. In both years most students were repeating earlier CAI assignments while new students were randomly assigned. Although there were three treatment conditions in year 2--MM, MRL and RL--only two of these were used in year 4: MM and RL. In both years the MM group performed significantly better on the CSTs and the CTBS computation subtest. In both years the only statistically significant treatment effects for the RL group are on the language CSTs. Although many reading and language treatment effects are positive, none but the language CST achieves statistical significance.

Table 4-27

One-Year Analysis for GRADE = 5 YEAR = 4.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 146df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	101	4.22	3.42	36.62	11.35		0.60
	RL	63	-		30.35	11.93	7.01	-
PART B	MM	101	5.09	4.38	34.34	10.21		0.77
	RL	63	-		27.52	9.48	6.60	-
MATH TOTAL	MM	101	9.31	4.31	70.96	20.73		0.76
	RL	63	-		59.87	20.57	12.27	-

CTBS	Treatment Group	N	Treatment Effect	(t) 142df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	94	3.61	2.99	29.39	8.63	6.98	0.52
	RL	67	-		24.91	9.01		-
CONCEPT	MM	94	-0.32	-0.56	12.15	4.70	3.35	-0.10
	RL	67	-		12.04	4.70		-
APPLICATION	MM	94	-0.58	-0.91	11.03	5.65	3.66	-0.16
	RL	67	-		11.06	5.39		-
MATH TOTAL	MM	94	2.70	1.44	52.57	16.51	10.89	0.25
	RL	67	-		48.01	16.78		-

Table 4-28

One-Year Analysis for GRADE = 5 YEAR = 4.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 128df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	87	-		38.93	10.38	6.22	-
	RL	61	0.98	0.85	40.06	9.57		0.16
PART B	MM	87	-		35.86	11.80	6.90	-
	RL	61	1.36	1.07	37.13	11.51		0.20
READING TOTAL	MM	87	-		74.79	21.40	11.97	-
	RL	61	2.35	1.06	77.20	20.59		0.20

CTBS	Treatment Group	N	Treatment Effect	(t) 138df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	94	-		18.02	8.34	4.50	-
	RL	67	1.05	1.35	18.73	8.04		0.23
COMPREHENSION	MM	94	-		18.19	8.56	4.74	-
	RL	67	1.48	1.81	19.04	8.74		0.31
READING TOTAL	MM	94	-		36.21	15.99	7.67	-
	RL	67	2.52	1.91	37.78	15.88		0.33

Table 4-29

One-Year Analysis for GRADE = 5 YEAR = 4.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 128df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	87	-		41.18	7.20	5.20	-
	RL	61	1.91	1.99	43.77	8.31		0.37
PART B	MM	87	-		37.76	8.34	5.22	-
	RL	61	2.85	2.95	40.54	8.16		0.55
LANGUAGE TOTAL	MM	87	-		78.94	14.29	8.49	-
	RL	61	4.76	3.03	84.31	15.31		0.56

CTBS	Treatment Group	N	Treatment Effect	(t) 138df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
SPELLING	MM	94	-		32.00	7.65	5.73	-
	RL	67	-0.54	-0.55	30.24	8.22		-0.09
MECHANICS	MM	94	-		10.87	4.29	3.09	-
	RL	67	0.66	1.24	11.01	4.18		0.21
EXPRESSION	MM	94	-		16.33	5.99	3.66	-
	RL	67	1.22	1.93	16.82	6.48		0.33
LANGUAGE TOTAL	MM	94	-		59.20	15.79	8.90	-
	RL	67	1.33	0.87	58.07	16.13		0.15

The Grade 6 Studies

The one-year studies for grade 6 are summarized as follows:

	Year 1	Year 2	Year 3	Year 4
Grade 6	CAI: MM, RR, RL, LL	Cohort Controls	CAI: MM, MRL, RL	Cohort Controls
	Comparisons	Comparisons	Comparisons	Comparisons

Three curriculums--mathematics, reading and language--were all available for grade 6. Different combinations of these three curriculums were studied to determine the effectiveness of CAI.

The Design and Analyses for Grade 6

Year 1. In the first year, the assumption was made that reading and language CAI curriculums covered different skills. All sixth graders were given two 10-minute sessions of CAI daily, but there were four treatment conditions. These conditions were as follows:

MM	Mathematics-Mathematics
RR	Reading-Reading
RL	Reading-Language
LL	Language-Language

The four treatments at the sixth-grade level allowed a separate comparison of the accomplishments of students in the reading and language CAI curriculums. Students were randomly assigned to one of the four treatment curriculums in CAI schools. Because the CAI treatment started in February of year 1 and CTBS tests were given in April, each student received 8 to 10 weeks of CAI before CTBS testing. The CSTs were given in late May after three months or more of CAI.

The research design at the sixth grade in year 1 was compromised by the actual conditions during implementation. Although students were randomly assigned to each of the four conditions, brighter students topped out of the language and reading curriculums. Some students topped out during the rapid-motion phase in the first 10 sessions of CAI; some topped out much later. Although students who topped out and were reassigned to mathematics were screened out of the analyses, the randomized design was compromised. Students remaining in the RR and, especially, the LL conditions were the slower students. Students in the RL condition did not top out as frequently because they spent only half as much time in each of the curriculums. Therefore the RL students are likely to be a brighter group than the RR or LL groups. One hopes the regression analyses compensate for the randomization problems, but we recognize the deficiencies of the design at this level.

Year 3. Most students in grade 6 in CAI schools in year 3 already had been exposed to one-and-one-half years of computer-assisted instruction. In grade 4 the students had been assigned to one of three treatment conditions: two sessions of math CAI daily (MM), one session of reading and one of language daily (RL), or a combination of one session of math daily with a second session which alternated between reading and language (MRL). In grade 5 and again in grade 6, returning students were given their original CAI treatments while new students were randomly assigned to one of the three conditions. Because of the LAUSD desegregation plan, there were no sixth graders in School 1 in year 3.

Results for Grade 6

Year 1. Table 4-30 presents the results for CST and CTBS mathematics scores. For the CST data, the treatment effects for the MM group are statistically significant. For the mathematics CST data, the adjusted mean for the MM group is almost one-and-one half standard deviations above the adjusted mean for the other groups combined. There are no statistically significant differences between the MM group and other groups on the CTBS mathematics subtests. Since the CTBS was administered only a few weeks after the onset of CAI, the failure to find differences is not surprising.

Table 4-31 gives the results for the CST and CTBS reading tests. For the CST data, statistically significant differences in the treatment effects are found for the RR group on part B and the total and for the RL group on part B. Overall the RR group did about twice as well as the RL group when compared to the MM group on the reading CST. The CTBS reading results may reflect some treatment effects of exposure to the CAI curriculum as well as the topping out phenomenon described earlier. Only the treatment effect for the RL group in reading comprehension is statistically significant, although all are positive.

Table 4-32 presents the results for the CST and CTBS language tests. For the CST data, treatment effects for the LL and the RL groups are all statistically significant, but there appeares to be little difference between them. As we have seen earlier, students receiving half as much CAI perform about half as well. This may indicate a ceiling effect for the test and the CAI curriculum. None of the treatment effects for the CTBS language subtests is statistically significant.

Overall, results for the CSTs in year 1 are significant and in the predicted direction. The CTBS results are not significant, as might have been expected since exposure to CAI was limited.

Table 4-30

One-Year Analysis for GRADE = 6 YEAR = 1.

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	176df	$\bar{X}$	SD	SD	T.E.
PART A	MM	60	6.87	8.46	35.35	10.66	4.89	1.40
	RR, LL, RL	134	-		25.47	5.94		-
PART B	MM	60	6.28	7.06	27.92	10.57	5.35	1.17
	RR, LL, RL	134	-		18.62	5.61		-
MATH	MM	60	13.15	8.65	63.27	20.79	9.15	1.44
TOTAL	RR, LL, RL	134	-		44.08	10.19		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	183df	$\bar{X}$	SD	SD	T.E.
COMPUTATION	MM	63	1.04	0.96	34.43	8.36	6.56	0.16
	RR, LL, RL	138	-		30.36	7.77		-
CONCEPTS	MM	63	-0.27	-0.55	14.41	4.60	2.91	-0.09
	RR, LL, RL	138	-		13.05	3.78		-
APPLICATION	MM	63	-0.39	-0.56	14.41	5.97	4.13	-0.09
	RR, LL, RL	138	-		12.34	5.25		-
MATH	MM	63	0.39	0.22	63.25	17.16	10.80	0.04
TOTAL	RR, LL, RL	138	-		55.75	14.17		-

Table 4-31

One-Year Analysis for GRADE = 6 YEAR = 1.

Posttest = CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 192df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	56	-		35.38	10.26	7.26	-
	RR	49	2.67	1.83	36.82	10.64		0.37
	RL	61	1.15	0.84	35.84	10.53		0.16
	LL	49	-2.36	-1.61	34.20	11.25		-0.33
PART B	MM	56	-		25.54	11.06	6.55	-
	RR	49	4.37	3.32	28.67	10.92		0.67
	RL	61	2.49	1.99	27.49	11.44		0.38
	LL	49	0.72	0.54	27.94	12.40		0.11
READING TOTAL	MM	56	-		60.91	19.91	12.45	-
	RR	49	7.04	2.82	65.49	20.79		0.57
	RL	61	3.64	1.54	63.33	20.94		0.29
	LL	49	-1.64	-0.65	62.14	22.58		-0.13

CTBS	Treatment Group	N	Treatment Effect	(t) 183df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	65	-		23.18	8.69	4.44	-
	RR	53	1.17	1.38	21.42	7.24		0.26
	RL	51	1.24	1.44	21.61	7.14		0.28
	LL	34	-0.71	-0.73	19.74	8.20		-0.16
COMPREHENSION	MM	65	-		23.66	10.26	5.64	-
	RR	53	2.56	2.36	23.25	7.78		0.45
	RL	51	2.86	2.61	23.57	6.74		0.51
	LL	34	0.49	0.39	21.44	8.79		0.09
READING TOTAL	MM	65	-		46.85	18.25	8.67	-
	RR	53	3.73	2.24	44.66	13.80		0.43
	RL	51	4.10	2.43	45.18	13.16		0.47
	LL	34	-0.23	-0.12	41.18	16.32		-0.03

Table 4-32

One-Year Analysis for GRADE = 6 YEAR = 1.

Posttest = CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 192df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	56	-		39.30	6.67	5.18	-
	RR	49	0.46	0.44	38.80	7.66		0.09
	RL	61	4.21	4.27	43.00	7.38		0.81
	LL	49	4.52	4.32	44.37	6.59		0.87
PART B	MM	56	-		34.04	8.05	5.27	-
	RR	49	0.60	0.57	33.78	6.68		0.11
	RL	61	3.65	3.64	37.20	7.61		0.69
	LL	49	3.90	3.67	38.45	8.58		0.74
LANGUAGE TOTAL	MM	56	-		73.34	13.64	8.98	-
	RR	49	1.06	0.59	72.57	13.38		0.12
	RL	61	7.86	4.59	80.20	14.20		0.88
	LL	49	8.42	4.64	82.82	14.10		0.94

CTBS	Treatment Group	N	Treatment Effect	(t) 173df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	64	-		35.47	8.77	6.07	-
	RR	54	-0.48	-0.41	32.44	8.03		-0.08
	RL	46	0.69	0.56	33.35	6.37		0.11
	LL	31	-0.62	-0.44	31.35	7.79		-0.10
MECHANICS	MM	64	-		10.53	4.34	2.95	-
	RR	54	0.85	1.50	10.98	3.64		0.29
	RL	46	0.53	0.89	10.57	3.40		0.18
	LL	31	0.25	0.36	9.58	4.04		0.08
EXPRESSION	MM	64	-		19.13	7.11	4.57	-
	RR	54	0.58	0.66	18.15	5.16		0.13
	RL	46	0.53	0.58	17.93	4.78		0.12
	LL	31	-0.40	-0.37	16.45	6.44		-0.09
LANGUAGE TOTAL	MM	64	-		65.13	17.71	10.18	-
	RR	54	0.96	0.49	61.57	14.43		0.09
	RL	46	1.76	0.85	61.85	10.66		0.17
	LL	31	-0.78	-0.32	57.39	14.61		-0.08

Year 3. Table 4-33 presents the results for CST and CTBS mathematics scores for sixth graders in year 3. Most students were in their third year of CAI with the same treatment conditions. For the CSTs the treatment effects for the MM and MRL groups are statistically significant overall as compared to RL students. In general, treatment effects for the MRL group are about half those of the MM group. For the CTBS mathematics data there are no statistically significant treatment effects, although the strongest effect is for the MM group in computation.

Table 4-34 gives the results for the CST and CTBS reading scores. For the CST data, none of the treatment effects is statistically significant, although differences favor the RL group over the MM group. For the CTBS data, treatment effects for the RL and MRL groups in reading vocabulary are statistically significant, with the adjusted means for the RL and MRL groups almost half a standard deviation above the adjusted means for the MM group.

Table 4-35 presents the results for the CST and CTBS language scores. For the CST data, treatment effects for the RL group are statistically significant for part A and the reading total. In general, treatment effects for the MRL group are about half of the treatment effects for the RL group. The adjusted mean for the RL group is .53 of a standard deviation higher than the adjusted mean for the MM group. None of the treatment effects for CTBS scores is statistically significant.

Table 4-33

One-Year Analysis for GRADE = 6 YEAR = 3.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 133df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	55	4.74	3.59	37.69	11.07	5.97	0.79
	MRL	54	3.20	2.54	35.39	10.17		0.54
	RL	41	-		32.71	9.19		-
PART B	MM	55	3.89	3.23	27.62	11.25	5.45	0.71
	MRL	54	1.80	1.56	25.54	10.02		0.33
	RL	41	-		24.12	7.63		-
MATH TOTAL	MM	55	8.62	3.75	65.30	21.83	10.43	0.83
	MRL	54	5.01	2.27	60.92	19.66		0.48
	RL	41	-		56.83	16.05		-

CTBS	Treatment Group	N	Treatment Effect	(t) 133df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	MM	51	2.39	1.51	33.21	9.94	7.25	0.33
	MRL	55	1.17	0.77	31.16	8.61		0.16
	RL	44	-		30.68	8.57		-
CONCEPTS	MM	51	0.16	0.22	14.39	5.23	3.36	0.05
	MRL	55	-0.29	-0.42	13.58	4.64		-0.09
	RL	44	-		14.32	4.08		-
APPLICATIONS	MM	51	1.16	1.20	13.65	6.20	4.44	0.26
	MRL	55	0.94	1.02	12.65	6.47		0.21
	RL	44	-	-	12.16	5.50		-
MATH TOTAL	MM	51	3.72	1.37	61.25	19.58	12.41	0.30
	MRL	55	1.82	0.70	57.40	18.03		0.15
	RL	44	-	-	57.16	15.37		-

Table 4-34

One-Year Analysis for GRADE = 6 YEAR = 3.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest mean- by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 122df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	45	-		37.71	11.28	5.87	-
	MRL	53	1.49	1.16	38.91	9.97		0.25
	RL	43	2.23	1.60	41.40	8.35		0.38
PART B	MM	45	-		31.18	11.17	6.54	-
	MRL	53	0.47	0.33	31.36	12.59		0.07
	RL	43	2.56	1.65	34.56	10.67		0.39
READING TOTAL	MM	45	-		68.89	21.43	10.97	-
	MRL	53	1.96	0.82	70.26	21.82		0.18
	RL	43	4.79	1.83	75.95	17.68		0.44

CTBS	Treatment Group	N	Treatment Effect	(t) 128df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	50	-		21.48	9.29	5.06	-
	MRL	56	2.58	2.44	23.21	9.26		0.51
	RL	43	2.28	2.03	24.33	8.99		0.45
COMPREHENSION	MM	50	-		24.54	11.06	5.71	-
	MRL	56	-0.36	-0.30	23.36	10.98		-0.06
	RL	43	0.18	0.14	25.26	9.66		0.03
READING TOTAL	MM	50	-		46.02	19.69	9.62	-
	MRL	56	2.22	1.10	46.57	19.61		0.23
	RL	43	2.46	1.15	49.60	17.92		0.26

Table 4-35

One-Year Analysis for GRADE = 6 YEAR = 3.

Posttest = CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 122df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	45	-		41.00	8.45	4.58	-
	MRL	53	0.98	0.98	41.96	7.56		0.21
	RL	43	2.75	2.52	44.95	6.37		0.60
PART B	MM	45	-		36.18	7.52	4.17	-
	MRL	53	0.93	1.02	37.02	6.93		0.22
	RL	43	1.34	1.35	38.88	5.42		0.32
LANGUAGE TOTAL	MM	45	-		77.18	15.23	7.64	-
	MRL	53	1.91	1.14	78.98	13.80		0.25
	RL	43	4.08	2.24	83.84	11.25		0.53

CTBS	Treatment Group	N	Treatment Effect	(t) 128df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	50	-		33.92	8.98	6.27	-
	MRL	56	-0.84	-0.64	34.09	9.95		-0.13
	RL	43	-0.19	-0.14	35.58	9.39		-0.03
MECHANICS	MM	50	-		11.64	4.36	3.14	-
	MRL	56	0.21	0.32	11.75	4.62		0.07
	RL	43	0.65	0.93	12.60	3.69		0.21
EXPRESSION	MM	50	-		18.76	7.97	4.36	-
	MRL	56	0.75	0.82	19.23	7.91		0.17
	RL	43	0.86	0.88	20.35	7.60		0.20
LANGUAGE TOTAL	MM	50	-		64.32	18.81	10.93	-
	MRL	56	0.12	0.05	65.07	20.90		0.01
	RL	43	1.32	0.54	68.53	18.59		0.12

Summary of the Grade 6 Data

For the sixth-grade data, the CSTs show that students assigned to a CAI curriculum did, in fact, perform better when tested on that curriculum. Results are statistically significant for the mathematics and language CSTs and for some of the reading CSTs.

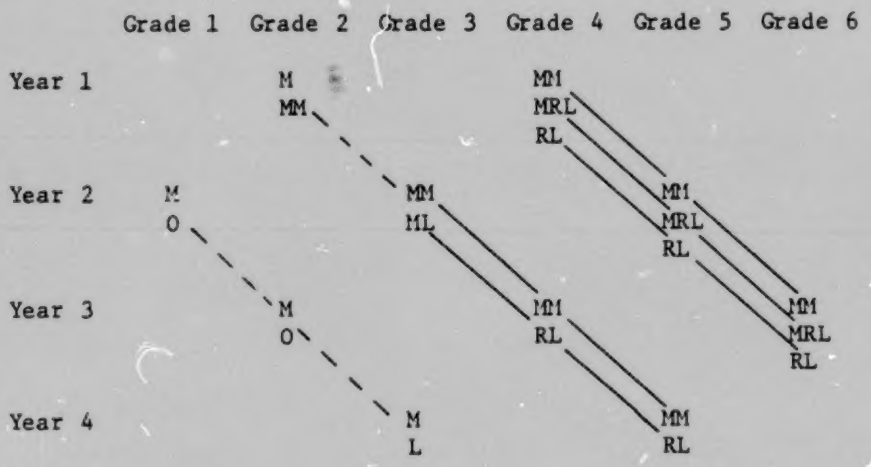
For the CTBS data only one year's results were applicable. In year 3, RL students performed significantly better on reading vocabulary than did the MM students. The MM students performed better on mathematics computation, although the effect is not statistically significant.

Chapter IV

LONGITUDINAL EXPERIMENTAL STUDIES

Introduction

One of the goals of this CAI study is to assess the effects of more than one year of exposure to the three CAI curriculums. This requires a longitudinal design in which CAI is used with the same group of students as they proceed through successive grades. We have already seen all of the components of the longitudinal studies as we reviewed the 12 one-year studies. A schematic description of the longitudinal design is as follows:



The letters indicate the treatments received by the students at designated years and grades. Solid lines indicate that individual students were assigned to the same treatment groups in the subsequent years. Dashed lines indicate that treatment groups were re-randomized in the succeeding year. There are three longitudinal studies: grade 1 to grade 3, grade 2 to grade 5, and grade 4 to grade 6. Besides allowing us to study the effect of long-term exposure to various CAI curriculums, this longitudinal design provides the opportunity of assessing the effects of changing curriculum mixes on some of the students in different years. The design also gives us some replication of certain aspects of the study under somewhat different conditions.

The Grade 1 to Grade 3 Longitudinal Study

The grade 1 to grade 3 longitudinal study is summarized as follows:

$$\begin{tikzcd}
\text{Grade 1} & \text{Grade 2} & \text{Grade 3} \\
M \arrow[r] \arrow[dr] & M \arrow[r] \arrow[dr] & M \\
O \arrow[r] \arrow[ur] & O \arrow[r] \arrow[ur] & L
\end{tikzcd}$$

where 0 stands for zero CAI curriculum exposure. For first and second grades, mathematics was the only curriculum available. Zero CAI exposure (0) was used as a control for mathematics CAI exposure. For third graders, mathematics and language curriculums were compared. Unlike the other two longitudinal studies, the procedures to randomize the assignment of curriculums to students were activated in each of the three years.

For the four CAI schools in year 2, classrooms at the first-grade level were randomly selected to receive or not receive 10 minutes of mathematics CAI curriculum. Pairs of classrooms were identified on the basis of a priori information. One number of each pair of classrooms was selected for CAI; the other was its control. In year 3, classrooms at the second-grade level were again randomly divided into two categories; one received the CAI mathematics curriculum the other did not. Within the CAI classrooms, students in the mathematics CAI curriculum were randomly assigned to either fixed or variable strands. The overall curriculum was the same but the method of presentation was different. Variable strands presented questions from all available strands of the mathematics curriculum in variable order, while fixed strands allowed the teacher to select the strand in which the student worked.

In year 4, both mathematics and language arts curriculums were available for third graders, and they were randomly assigned within classrooms to either mathematics CAI or language arts CAI for 10 minutes daily. The third-grade design provided a completely randomized comparison between the mathematics and language curriculums.

Because the randomization procedures occurred every year, there were many combinations of CAI treatment sequences across the three-year experimental period. For example, there were four treatment sequences across grades 1 and 2 if we do not distinguish between fixed and variable strands. There were OO, OM, MO and MM, where O stands for no CAI exposure. This two-year longitudinal study provided a comparison of the benefits of first and/or second grade CAI instruction in mathematics. The language CAI curriculum for third graders in year 4 served as a control for the mathematics CAI treatment effect. By the end of grade 3 there were eight possible CAI sequences for students in the grades 1-3 CAI cohort.

Results for the Longitudinal Data, Grades 1-3

The analysis of the data for this longitudinal group is complicated by the fact that, at the end of the third year of the study, there were eight treatment conditions among less than 100 CAI students who remained.

Four sets of analyses will be described on the following pages: grades 1-2 analyses, grades 1-3 analyses, CAI students vs. cohort controls, and CAI students vs. comparisons.

Table 4-36 presents the results for the CST and CTBS mathematics scores of students in CAI schools in grades 1 and 2. By the end of grade 2 there were four treatment groups: some students had no mathematics CAI either year (00), some had CAI only in grade 1 (MO), some had CAI only in grade 2 (OM), and some had CAI both years (MM). The CST results show that treatment effects for the OM and MM groups are statistically significant when compared to the group with no CAI. In terms of the residual standard deviation, the adjusted means of groups MO, OM, and MM are .25, .71, and .66 of a standard deviation above the adjusted mean for students without CAI.

Results for the CTBS show that the treatment effects for the MM group for computation and mathematics total are both statistically significant. The treatment effects are orderly; i.e., the more mathematics CAI or the more recent the CAI experience, the higher the treatment effect. For the CTBS mathematics total, the adjusted means for the MO, OM, and MM groups are .25, .53, and .71 of a standard deviation above the adjusted mean for the students without CAI.

Table 4-36

Longitudinal Analysis for GRADE 1 to GRADE 2.

Period = YEAR 2 to YEAR 3.

Posttest = CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 98df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	OO	27	-		33.48	11.43	9.06	-
	MO	22	2.60	0.95	34.59	10.52		0.29
	OM	37	4.67	1.81	39.70	11.07		0.51
	MM	25	5.32	2.02	37.84	9.05		0.59
PART B	OO	27	-		19.26	12.98	9.54	-
	MO	22	1.68	0.58	20.05	10.07		0.18
	OM	37	7.66	2.82	30.19	13.30		0.80
	MM	25	6.17	2.22	25.04	13.05		0.65
MATH TOTAL	OO	27	-		52.74	23.15	17.40	-
	MO	22	4.27	0.81	54.64	19.90		0.25
	OM	37	12.32	2.49	69.89	23.15		0.71
	MM	25	11.49	2.27	62.88	21.42		0.66

CTBS	Treatment Group	N	Treatment Effect	(t) 104df.	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	OO	31	-		14.39	6.90	5.17	-
	MO	21	1.83	1.18	15.05	6.70		0.35
	OM	40	2.30	1.60	18.18	6.59		0.44
	MM	25	3.47	2.38	18.00	6.18		0.67
CONCEPTS AND APPLICATIONS	OO	31	-		13.94	5.54	3.68	-
	MO	21	-0.13	-0.11	13.24	5.56		-0.03
	OM	40	1.64	1.61	16.85	5.30		0.45
	MM	25	1.85	1.78	15.32	4.06		0.50
MATH TOTAL	OO	31	-		28.32	11.29	7.50	-
	MO	21	1.70	0.75	28.29	10.66		0.23
	OM	40	3.94	1.90	35.03	11.26		0.52
	MM	25	5.31	2.51	33.32	9.31		0.71

Table 4-37 presents the results for the CST and CTBS mathematics scores for longitudinal students in grades 1-3. Whereas the two-year regressions showed four groups of students, the number is doubled for the three-year regressions. Students in each of the previous four groups were assigned either mathematics or language CAI in grade 3. Table 4-37 collapses the eight groups of students into four groups as follows:

OOL = 0 years of mathematics CAI
MOO, OMO, OOM = 1 year of mathematics CAI
MOM, OMM, MMO = 2 years " " "
MMM = 3 years " " "

The CST results show statistically significant treatment effects for most of the CAI conditions, and the treatment effects are ordered. The more mathematics CAI, the greater the treatment effect. For the total CST, the adjusted means for students with one, two or three years of mathematics CAI are .74, .91, and 1.54 of a standard deviation above the adjusted mean for students without CAI.

The CTBS results are more confused. Many bilingual students were not tested with the CTBS in the final year of the study. The decision not to test bilingual students in one school was beyond the control of the CAI project. It was unfortunate in that the loss of students reduced the number of students with three years of CAI to four. None of the treatment effects for CTBS subtests is significant. Nevertheless it is interesting to note that for computation, the adjusted means for students with one and two years of CAI are .29 and .61 of a standard deviation above the adjusted mean for students with no CAI experience. Those results are not statistically significant, but they do follow the general trend.

Table 4-37

Longitudinal Analysis for GRADE 1 to GRADE 3.

Period = YEAR 2 to YEAR 4.

Posttest = CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 64df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	0	14	-		29.57	14.04		-
	1	27	8.61	2.43	45.11	11.02	9.21	0.93
	2	32	8.89	2.73	40.50	14.41		0.96
	3	12	12.20	2.71	42.17	10.42		1.32
PART B	0	14	-		20.14	9.30		-
	1	27	3.79	1.07	28.44	13.92	9.21	0.41
	2	32	6.35	1.95	28.44	14.81		0.69
	3	12	13.44	2.98	30.58	12.50		1.46
MATH TOTAL	0	14	-		49.71	22.68		-
	1	27	12.40	1.93	79.30	24.33	16.67	0.74
	2	32	15.25	2.59	68.94	27.70		0.91
	3	12	25.64	3.15	72.75	20.36		1.54

CTBS	Treatment Group	N	Treatment Effect	(t) 46df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	0	13	-		21.85	10.02		-
	1	24	1.81	0.67	33.96	10.51	6.27	0.29
	2	26	3.81	1.49	27.15	11.82		0.61
	3	4	0.89	0.21	25.50	11.41		0.14
CONCEPTS	0	13	-		9.69	6.18		-
	1	24	0.10	0.07	16.42	6.44	3.31	0.03
	2	26	1.45	1.08	12.62	6.62		0.44
	3	4	0.12	0.05	11.50	5.85		0.04
APPLICATIONS	0	13	-		7.77	5.42		-
	1	24	0.48	0.31	14.75	5.68	3.57	0.13
	2	26	0.66	0.46	10.54	6.78		0.18
	3	4	-0.85	-0.36	8.00	7.71		-0.24
MATH TOTAL	0	13	-		39.31	20.47		-
	1	24	2.40	0.51	65.13	21.06	10.84	0.22
	2	26	5.93	1.34	50.31	24.26		0.55
	3	4	0.15	0.02	45.00	23.33		0.01

Table 4-38 gives the results for CST and CTBS mathematics scores for students in the grades 1-3 longitudinal CAI group compared to students in the cohort control group in the same schools a year earlier. We have just looked at results for the CAI group, and we know that some students in that group had no CAI at all while others had from one to three years of CAI. In these analyses, we make no differentiation among CAI students. We simply compare the total group with those who were in grades 1-3 in the same schools one year earlier.

The CST data show that the treatment effects for the CAI group are statistically significant. When the treatment effects are expressed in terms of the residual standard deviation, the CAI group is .80 of a standard deviation higher than their cohort controls.

The CTBS data likewise show that the treatment effects for the CAI group are statistically significant. Adjusted means for the CAI group are from .38 to .51 of a standard deviation above the adjusted means for the cohort controls.

Table 4-38

Longitudinal Analysis for GRADE 1 to GRADE 3: CAI VS COHORT.

Period = YEAR 1 to YEAR 3 FOR COHORT. YEAR 2 to YEAR 4 FOR CAI.

Posttest = CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 210df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	CAI	97	8.23	5.34	40.96	13.85	10.61	0.78
	COHORT	125	-		38.19	13.77		-
PART B	CAI	97	7.00	4.79	29.75	13.80	10.08	0.69
	COHORT	125	-		26.76	11.46		-
MATH TOTAL	CAI	97	15.23	5.55	70.71	26.38	18.93	0.80
	COHORT	125	-		64.95	23.74		-

CTBS	Treatment Group	N	Treatment Effect	(t) 185df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	CAI	79	4.46	3.28	28.91	11.35	8.72	0.51
	COHORT	118	-		28.45	12.03		-
CONCEPTS	CAI	79	1.99	2.95	14.18	6.38	4.31	0.46
	COHORT	118	-		14.27	6.15		-
APPLICATION	CAI	79	1.87	2.46	11.53	6.82	4.88	0.38
	COHORT	118	-		11.63	6.81		-
MATH TOTAL	CAI	79	8.33	3.44	54.62	23.12	15.48	0.54
	COHORT	118	-		54.35	23.06		-

Table 4-39 gives the results for CST and CTBS mathematics scores for students in the grades 1-3 longitudinal CAI group compared to students in two comparison schools.

For the CST data, the treatment effects for the CAI group are all statistically significant. The CAI group overall is .76 of a standard deviation above the adjusted mean of the comparison group.

For the CTBS data, significant treatment effects are found for concepts, applications, and the CTBS total. For the total score, the CAI group is about half a standard deviation higher than the comparison group.

Table 4-39

Longitudinal Analysis for GRADE 1 to GRADE 3: CAI VS COMPARISON.

Period = YEAR 1 to YEAR 3 FOR COMPARISON. YEAR 2 to YEAR 4 FOR CAI.

Posttest = CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 1-4 vs 5-6.

					Posttest			
CST	Treatment Group	N	Treatment Effect	(t) 199df	$\bar{X}$	SD	Residual SD	Standardized T.E.
PART A	CAI	97	9.28	5.45	40.96	13.85	11.21	0.83
	COMPARISON	111	-		34.18	12.37		-
PART B	CAI	97	6.09	3.88	29.75	13.80	10.32	0.59
	COMPARISON	111	-		25.51	10.79		-
MATH TOTAL	CAI	97	15.37	4.98	70.71	26.38	20.31	0.76
	COMPARISON	111	-		59.69	22.42		-

					Posttest			
CTBS	Treatment Group	N	Treatment Effect	(t) 178df	$\bar{X}$	SD	Residual SD	Standardized T.E.
COMPUTATION	CAI	79	1.37	0.88	28.91	11.35	9.29	0.15
	COMPARISON	108	-		29.50	10.74		-
CONCEPTS	CAI	79	2.91	3.55	14.18	6.38	4.85	0.60
	COMPARISON	108	-		12.29	5.35		-
APPLICATIONS	CAI	79	3.91	5.15	11.53	6.83	4.50	0.87
	COMPARISON	108	-		8.31	4.74		-
MATH TOTAL	CAI	79	8.20	3.09	54.62	23.12	15.71	0.52
	COMPARISON	108	-		50.09	17.64		-

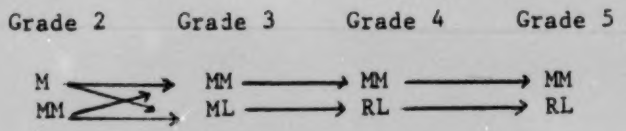
Discussion for Grades 1-3

The treatment effects for students assigned to mathematics CAI are remarkably consistent. The CST results for CAI students across three years average .80 of a standard deviation above the adjusted mean for students with no CAI. When CAI students are compared with cohort controls in the same schools a year earlier or with students in comparison schools, CAI students again are .80 or .76 of a standard deviation higher on the CST. Clearly, CAI students are acquiring the skills on which they receive drill and practice in the CAI mathematics curriculum.

The CTBS results are less remarkable but nevertheless give evidence that drill and practice CAI helps students' performance on standardized tests. The adjusted mean score for CAI students averages about half a standard deviation above the adjusted mean score for cohort controls or comparison-school students on the mathematics CTBS total.

The Grade 2 to Grade 5 Longitudinal Study

The grade 2 to grade 5 longitudinal study is summarized as follows:



The purpose of this longitudinal study was to compare the pure mathematics curriculum versus the reading and language combined curriculums. The longitudinal study started in year 1. Second graders were randomly assigned to one or two sessions of mathematics CAI during the second semester. As has been mentioned before, this design was extremely disruptive to second-grade classrooms and met with a good deal of teacher opposition. In grade 3, students were assigned either two sessions of mathematics CAI or one session of mathematics and one of language CAI. Several options had been contemplated, including a different design in school 3, until January 1978, when treatments were finalized as described. Students who had received mathematics and language CAI in grade 3 received reading and language CAI in grade 4. In year 4, the fifth graders continued the same treatment as they received in fourth grade. Although students had been exposed to CAI on a daily basis in grades 2 and 3, in grade 4 classrooms were assigned to the CAI lab either on Monday, Wednesday and Friday, or Tuesday and Thursday. In grade 5, the schedule was back to a daily basis. The grade 3 to 5 segment of the longitudinal study was selected for major emphasis because of the initial startup problems in grade 2 and because from grades 3-5 the two CAI groups began to increase their differentiation. The MM group retained the double dose of mathematics treatment for three consecutive years while the other longitudinal group switched to the reading and language curriculums.

Results for the Longitudinal Data, Grades 2-5

Five sets of analyses will be presented in this section. First we will present the regression for CAI students from grades 3-5, comparing those who received only mathematics CAI with those who received mathematics/language in grade 3 and reading/language in grades 4 and 5. Because attrition had reduced the number of students for the three-year regression to a maximum of 91, two two-year regressions are reported for grades 3-4 (N=143) and grades 4-5 (N=106). Finally we will present two sets of regressions comparing CAI students with cohort controls in the same schools a year earlier and with students in comparison schools.

Grades 3-5 CAI. Table 4-40 presents the results for the CST and CTBS mathematics scores for longitudinal CAI students in grades 3-5. For the CST data, treatment effects for both parts and the total CST are statistically significant. The MM students are more than one standard deviation above the RL students on the CST even though the RL students had, in fact, been exposed to the mathematics CAI curriculum for a year in grade 3. For the CTBS data, the treatment effect for the computation subtest is statistically significant, with MM students about three-quarters of a standard deviation above the RL group. The rest of the treatment effects for the CTBS subtests and total are not statistically significant.

Table 4-41 presents the results for the CST and CTBS reading tests. None of the treatment effects is statistically significant.

Table 4-42 presents the results for the CST and CTBS language tests. For the CST data, the treatment effects for the RL group in language are all statistically significant, with the performance of the RL group almost three-quarters of a standard deviation above that of the MM group. Treatment effects for the CTBS subtests are all positive but none is statistically significant.

Table 4-40

Longitudinal Analysis for GRADE 3 to GRADE 5.

PERIOD = YEAR 2 to YEAR 4.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 52df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	57	8.05	4.23	38.40	10.55	6.81	1.18
	RL	30	-		32.53	10.37		-
PART B	MM	57	6.05	3.29	35.44	10.26	6.57	0.92
	RL	30	-		29.87	8.66		-
MATH	MM	57	14.10	4.17	73.84	19.78	12.09	1.17
TOTAL	RL	30	-		62.40	18.07		-

CTBS	Treatment Group	N	Treatment Effect	(t) 54df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	MM	58	5.46	2.89	29.95	8.56	6.88	0.79
	RL	32	-		25.41	9.20		-
CONCEPTS	MM	58	-0.37	-0.37	12.02	5.04	3.64	-0.10
	RL	32	-		12.53	5.09		-
APPLICATIONS	MM	58	-0.23	-0.20	11.26	5.68	4.26	-0.05
	RL	32	-		11.38	5.79		-
MATH	MM	58	4.86	1.48	53.22	16.54	11.93	0.41
TOTAL	RL	32	-		49.31	17.69		-

Table 4-41

Longitudinal Analysis for GRADE 3 to GRADE 5.

PERIOD = YEAR 2 to YEAR 4.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 51df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	55	-		39.40	10.08	6.88	-
	RL	30	2.20	1.19	42.40	7.23		0.32
PART B	MM	55	-		36.06	11.85	8.10	-
	RL	30	2.03	0.93	39.43	9.55		0.25
READING TOTAL	MM	55	-		75.46	20.89	13.49	-
	RL	30	4.23	1.17	81.83	15.84		0.31

CTBS	Treatment Group	N	Treatment Effect	(t) 53df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	58	-		18.41	8.60	4.69	-
	RL	33	-0.17	-0.14	19.46	8.39		-0.04
COMPREHENSION	MM	58	-		18.59	9.44	4.94	-
	RL	33	1.17	0.87	19.00	9.38		0.24
READING TOTAL	MM	58	-		37.00	17.20	8.30	-
	RL	33	0.99	0.44	38.46	16.92		0.12

Table 4-42

Longitudinal Analysis for GRADE 3 to GRADE 5.

PERIOD = YEAR 2 to YEAR 4.

Posttest= CST AND CTBS. Subject = LANGUAGE.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 51df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	55	-		41.33	7.58	6.29	-
	RL	30	3.66	2.17	45.63	8.16		0.58
PART B	MM	55	-		38.22	8.03	5.33	-
	RL	30	3.32	2.32	42.33	7.34		0.62
LANGUAGE TOTAL	MM	55	-		79.55	14.18	9.80	-
	RL	30	6.98	2.66	87.96	14.22		0.71

CTBS	Treatment Group	N	Treatment Effect	(t) 53df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	58	-		32.02	8.27	5.95	-
	RL	33	0.33	0.20	32.82	8.12		0.06
MECHANICS	MM	58	-		11.33	4.26	3.23	-
	RL	33	1.28	1.47	11.76	3.78		0.40
EXPRESSION	MM	58	-		16.32	6.25	4.00	-
	RL	33	0.95	0.89	17.00	6.81		0.24
LANGUAGE TOTAL	MM	58	-		59.66	16.65	9.46	-
	RL	33	2.56	1.00	61.58	15.49		0.27

Grades 3-4 CAI. On the next few pages are the data for a two-year longitudinal study of grades 3 to 4 in years 2 to 3. Table 4-43 presents the results for the CST and CTBS mathematics dependent variables. For the CST data, all of the treatment effects for the MM group are statistically significant, with the performance of the MM group about one standard deviation higher than the performance of the RL group. For the CTBS data, treatment effects for computation and for the mathematics total are both statistically significant, with the MM group more than half a standard deviation above the RL group. The treatment effects for the remaining CTBS subtests are positive but not statistically significant.

Table 4-44 gives the results for the CST and CTBS reading dependent variables. None of the treatment effects is statistically significant.

Table 4-45 gives the results for the CST and CTBS language dependent variables. For the CST data, all of the treatment effects for the RL group are statistically significant. The adjusted mean of the RL group is more than half a standard deviation above that of the MM group. For the CTBS data, none of the treatment effects is statistically significant, although the treatment effect for mechanics approaches significance.

Table 4-43

Longitudinal Analysis for GRADE 3 to GRADE 4.

PERIOD = YEAR 2 to YEAR 3.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	102df	$\bar{X}$	SD	SD	T.E.
PART A	MM	87	7.34	5.12	42.55	10.25	7.21	1.02
	RL	47	-		33.85	11.04		-
PART B	MM	87	4.83	3.76	28.64	11.92	6.46	0.75
	RL	47	-		22.58	11.12		-
MATH TOTAL	MM	87	12.16	4.97	71.19	21.31	12.32	0.99
	RL	47	-		56.43	21.52		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
Subtest	Group	N	Effect	105df	$\bar{X}$	SD	SD	T.E.
COMPUTATION	MM	90	4.60	3.08	38.70	9.30	7.77	0.59
	RL	50	-		35.02	10.54		-
CONCEPTS	MM	90	0.90	1.07	16.67	6.06	4.33	0.21
	RL	50	-		16.44	6.33		-
APPLICATIONS	MM	90	1.62	1.88	14.73	6.76	4.48	0.36
	RL	50	-		14.18	7.58		-
MATH TOTAL	MM	90	7.12	2.76	70.10	19.61	13.39	0.53
	RL	50	-		65.64	22.53		-

Table 4-44

Longitudinal Analysis for GRADE 3 to GRADE 4.

PERIOD = YEAR 2 to YEAR 3.

Posttest= CST AND CTBS   Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 104df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	89	-		48.51	10.89	8.25	-
	RL	48	1.04	0.64	50.65	7.87		0.13
PART B	MM	89	-		33.80	12.63	7.80	-
	RL	48	1.26	0.82	35.83	10.00		0.16
READING	MM	89	-		82.30	22.11	14.29	-
TOTAL	RL	48	2.30	0.82	86.48	16.41		0.16

CTBS	Treatment Group	N	Treatment Effect	(t) 107df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	89.	-		22.44	10.04	5.05	-
	RL	53	0.19	0.20	22.28	11.04		0.04
COMPREHENSION	MM	89	-		25.90	12.04	6.41	-
	RL	53	0.10	0.08	25.81	12.49		0.02
READING	MM	89	-		48.34	21.42	10.04	-
TOTAL	RL	53	0.29	0.15	48.09	22.19		0.03

Table 4-45

Longitudinal Analysis for GRADE 3 to GRADE 4.

PERIOD = YEAR 2 to YEAR 3.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 104df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	89	-		42.43	10.28	7.38	-
	RL	48	2.98	2.05	46.71	7.51		0.40
PART B	MM	89	-		36.20	10.42	6.92	-
	RL	48	4.90	3.59	42.17	9.18		0.71
LANGUAGE	MM	89	-		79.25	19.83	13.31	-
TOTAL	RL	48	7.89	3.00	88.88	16.15		0.59

CTBS	Treatment Group	N	Treatment Effect	(t) 107df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	89	-		29.11	10.11	7.19	-
	RL	53	-1.61	-1.19	27.06	10.30		-0.22
MECHANICS	MM	89	-		11.18	4.84	3.26	-
	RL	53	1.11	1.80	12.06	4.79		0.34
EXPRESSION	MM	89	-		17.67	7.69	4.74	-
	RL	53	0.72	0.80	18.04	7.34		0.15
LANGUAGE	MM	89	-		57.97	20.64	11.63	-
TOTAL	RL	53	0.21	0.10	57.15	20.15		0.02

Grades 4-5 CAI. On the next few pages are the data for a two-year longitudinal study of grades 4 to 5 in years 3 to 4. Table 4-46 presents the results for the CST and CTBS mathematics performance. For the CST data, all of the treatment effects for the MM group are statistically significant, and the performance of the MM students is about one standard deviation higher than the performance of RL students. For the CTBS data, only the treatment for computation is statistically significant, with the performance of MM students more than half a standard deviation above that of the RL students.

Table 4-47 presents the results for the CST and CTBS reading dependent variables. For the CST data, all of the treatment effects are statistically significant, with the performance of the RL group about three-quarters of a standard deviation above that of the MM group. None of the treatment effects for the RL group on CTBS reading subtests is statistically significant.

Table 4-48 gives the results for the CST and CTBS language subtests. For the CST, all of the treatment effects are statistically significant. The adjusted mean for the RL group on the total CST is more than one standard deviation above the adjusted mean for the MM group. None of the treatment effects for the RL group on the CTBS language subtests is significant.

Table 4-46

Longitudinal Analysis for GRADE 4 to GRADE 5.

PERIOD = YEAR 3 to YEAR 4.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 1-4.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	67df	$\overline{X}$	SD	SD	T.E.
PART A	MM	64	6.71	4.59	38.41	11.04	5.74	1.17
	RL	32	-		32.28	9.82		-
PART B	MM	64	5.16	3.50	35.78	10.36	5.79	0.89
	RL	32	-		30.09	8.64		-
MATH TOTAL	MM	64	11.87	4.66	74.19	20.47	10.02	1.18
	RL	32	-		62.38	17.51		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	66df	$\overline{X}$	SD	SD	T.E.
COMPUTATION	MM	64	3.81	2.24	29.11	8.65	6.65	0.57
	RL	30	-		25.27	9.35		-
CONCEPTS	MM	64	-0.74	-0.80	11.86	4.85	3.58	-0.21
	RL	30	-		12.77	5.25		-
APPLICATION	MM	64	-0.78	-0.79	10.86	5.40	3.87	-0.20
	RL	30	-		11.67	5.97		-
MATH TOTAL	MM	64	2.29	0.81	51.83	16.23	11.04	0.21
	RL	30	-		49.70	18.24		-

Table 4-47

Longitudinal Analysis for GRADE 4 to GRADE 5.

PERIOD = YEAR 3 to YEAR 4.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 77df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	71	-		39.94	9.37	6.18	-
	RL	35	3.32	2.23	42.69	6.47		0.54
PART B	MM	71	-		36.92	11.22	7.42	-
	RL	35	5.56	3.10	40.34	8.18		0.75
READING	MM	71	-		76.86	19.70	12.18	-
TOTAL	RL	35	8.88	3.02	83.03	13.65		0.73

CTBS	Treatment Group	N	Treatment Effect	(t) 75df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	72	-		17.69	7.54	4.39	-
	RL	34	0.62	0.56	18.09	6.90		0.14
COMPREHENSION	MM	72	-		17.49	7.90	4.81	-
	RL	34	1.29	1.05	17.94	8.29		0.27
READING	MM	72	-		35.18	14.37	7.53	-
TOTAL	RL	34	1.90	1.00	36.03	14.38		0.25

Table 4-48

Longitudinal Analysis for GRADE 4 to GRADE 5.

PERIOD = YEAR 3 to YEAR 4.

Posttest= CST AND CTBS   Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 77df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	71	-		41.61	7.04	5.7[illegible]	-
	RL	35	5.24	3.75	46.03	7.39		0.90
PART B	MM	71	-		38.39	7.89	4.85	-
	RL	35	4.43	3.78	42.09	7.06		0.91
LANGUAGE TOTAL	MM	71	-		80.00	13.48	8.47	-
	RL	35	9.67	4.73	88.11	12.97		1.14

CTBS	Treatment Group	N	Treatment Effect	(t) 75df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
SPELLING	MM	72	-		31.83	7.43	5.35	-
	RL	34	0.11	0.08	30.65	7.95		0.02
MECHANICS	MM	72	-		10.90	4.04	3.44	-
	RL	34	0.77	0.89	11.32	4.01		0.22
EXPRESSION	MM	72	-		16.10	5.42	4.23	-
	RL	34	0.55	0.52	15.97	5.74		0.13
LANGUAGE TOTAL	MM	72	-		58.83	14.64	10.26	-
	RL	34	1.44	0.56	57.94	14.83		0.14

Grades 3-5 vs. cohort controls. On the next few pages are the data for a three-year longitudinal study comparing CAI students with their cohort controls in the same schools one year earlier. Table 4-49 presents the results for the CST and CTBS mathematics data. For the CST, the treatment effects for the MM group are all statistically significant, as are 2 out of 3 of the effects for the RL group. The RL group is almost half a standard deviation and the MM group is more than one-and-one-quarter standard deviations above the adjusted mean of the cohort controls. Discussion of the performance of the RL group will be covered in the discussion section at the end of the presentation of results. For the CTBS data, treatment effects for the MM group on computation and mathematics total are statistically significant. Treatment effects on the remaining subtests for the MM group and all the subtests for the RL group are not significant.

Table 4-50 presents the reading results. For the CST data, all the treatment effects for the RL group and the treatment effects for the the MM group on part A are statistically significant. For the CTBS data, only the treatment effects for vocabulary are statistically significant, and they are roughly equivalent for the MM and RL groups.

Table 4-51 presents the language results. For the CST data, treatment effects on the language total are statistically significant for both the RL and MM group. Adjusted means for the MM students are almost half a standard deviation above their cohort controls. Adjusted means for the RL students are more than a standard deviation above the cohort controls for the language CST. For the CTBS data, there are significant treatment effects for both the MM and RL groups in language mechanics and for the MM group in language total.

Table 4-49

Longitudinal Analysis for GRADE 3 to GRADE 5: CAI VS COHORTS.

PERIOD = YEAR 2 to YEAR 4 FOR CAI AND YEAR 1 to YEAR 3 FOR COHORTS.

Posttest= CST AND CTBS   Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 188df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	58	11.88	7.37	37.60	11.20	9.85	1.21
	RL	29	4.83	2.30	32.41	10.27		0.49
	COHORT	111	-		25.10	11.62		-
PART B	MM	58	8.21	6.73	34.69	10.90	7.45	1.10
	RL	29	2.57	1.62	30.34	8.92		0.34
	COHORT	111	-		25.66	8.17		-
MATH TOTAL	MM	58	20.09	7.68	72.29	21.08	16.00	1.26
	RL	29	7.40	2.17	62.76	18.33		0.46
	COHORT	111	-		50.76	18.70		-

CTBS	Treatment Group	N	Treatment Effect	(t) 193df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	60	5.22	4.37	29.43	8.55	7.41	0.70
	RL	30	0.58	0.38	25.57	9.47		0.08
	COHORT	113	-		23.96	9.01		-
CONCEPTS	MM	60	0.62	1.10	11.95	5.02	3.49	0.18
	RL	30	0.39	0.53	12.43	5.24		0.11
	COHORT	113	-		11.05	4.10		-
APPLICATIONS	MM	60	1.27	1.71	11.05	5.70	4.59	0.28
	RL	30	1.02	1.07	11.30	5.97		0.22
	COHORT	113	-		9.49	5.19		-
MATH TOTAL	MM	60	7.10	3.42	52.43	16.68	12.88	0.55
	RL	30	1.99	0.74	49.30	18.26		0.15
	COHORT	113	-		44.50	16.22		-

Table 4-50

Longitudinal Analysis for GRADE 3 to GRADE 5: CAI VS COHORTS.

PERIOD = YEAR 2 to YEAR 4 FOR CAI AND YEAR 1 to YEAR 3 FOR COHORTS.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 181df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	55	2.98	2.12	38.55	10.27	8.39	0.35
	RL	30	5.51	3.13	42.07	7.20		0.66
	COHORT	108	-		35.92	11.40		-
PART B	MM	55	1.00	0.60	34.95	12.27	9.96	0.10
	RL	30	4.22	2.02	39.00	9.61		0.42
	COHORT	108	-		34.20	12.66		-
READING TOTAL	MM	55	3.98	1.38	73.49	21.56	17.30	0.23
	RL	30	9.73	2.68	81.07	15.84		0.56
	COHORT	108	-		70.12	23.38		-

CTBS	Treatment Group	N	Treatment Effect	(t) 193df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
VOCABULARY	MM	60	1.76	2.11	18.40	8.54	5.17	0.34
	RL	31	2.14	2.01	19.42	8.56		0.41
	COHORT	114	-		16.78	7.42		-
COMPREHENSION	MM	60	1.07	1.09	18.33	9.37	6.12	0.17
	RL	31	1.21	0.96	18.84	9.66		0.20
	COHORT	114	-		17.44	7.64		-
READING TOTAL	MM	60	2.83	1.78	36.73	17.03	6.45	0.44
	RL	31	3.35	1.64	38.26	17.40		0.52
	COHORT	114	-		34.22	14.01		-

Table 4-51

Longitudinal Analysis for GRADE 3 to GRADE 5: CAI VS COHORTS.

PERIOD = YEAR 2 to YEAR 4 FOR CAI AND YEAR 1 to YEAR 3 FOR COHORTS.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 181df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	55	4.04	2.97	40.80	7.81	8.14	0.50
	RL	30	8.10	4.75	45.43	8.13		0.99
	COHORT	108	-		37.15	11.85		-
PART B	MM	55	1.56	1.55	37.78	8.00	6.03	0.26
	RL	30	5.12	4.05	41.77	7.43		0.85
	COHORT	108	-		36.40	8.04		-
LANGUAGE TOTAL	MM	55	5.59	2.69	78.58	14.27	12.47	0.45
	RL	30	13.22	5.06	87.20	14.15		1.06
	COHORT	108	-		73.55	18.80		-

CTBS	Treatment Group	N	Treatment Effect	(t) 193df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	60	1.28	1.23	31.88	8.20	6.45	0.20
	RL	31	1.32	0.99	32.65	8.23		0.20
	COHORT	114	-		31.06	8.69		-
MECHANICS	MM	60	1.56	2.90	11.17	4.23	3.34	0.47
	RL	31	1.63	2.36	11.71	3.88		0.49
	COHORT	114	-		9.80	4.45		-
EXPRESSION	MM	60	0.72	0.99	16.23	6.29	4.49	0.16
	RL	31	0.79	0.85	16.90	6.88		0.18
	COHORT	114	-		15.70	6.65		-
LANGUAGE TOTAL	MM	60	3.56	2.06	59.28	16.61	10.70	0.33
	RL	31	3.73	1.69	61.26	15.61		0.35
	COHORT	114	-		56.56	17.30		-

Grades 2-5 CAI vs. comparison students. On the next few pages are the tables for a four-year longitudinal study of CAI students compared to students in two different schools in the same years. Table 4-52 presents the mathematics results. For the CST data, treatment effects for the MM group are all statistically significant, while treatment effects for the RL group are not. The MM students performed on the average more than one standard deviation above the adjusted mean for comparison students. For the CTBS data, only the treatment effect for the MM group on computation is statistically significant and equivalent to .45 of a standard deviation.

Table 4-53 presents the reading results. None of the treatment effects is significant either for the CST or CTBS data.

Table 4-54 presents the language results. For the CST data, statistically significant treatment effects were achieved by the RL group in part A and the total language CST. The adjusted mean for the RL group is .46 of a standard deviation higher than the adjusted mean of the comparison group. For the CTBS, none of the treatment effects is significant.

Table 4-52

Longitudinal Analysis for GRADE 2 to GRADE 5: CAI VS COMPARISONS.

PERIOD = YEAR 1 to YEAR 4.

Posttest= CST AND CTBS Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group,
Schools = 2-4 vs 5-6.

CST	Treatment Group	N	Treatment Effect	(t) 157df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	44	8.61	5.25	39.05	11.00	8.44	1.02
	RL	31	1.57	0.87	31.84	10.81		0.19
	COMPARISON	90	-		29.82	10.35		-
PART B	MM	44	6.57	4.46	36.00	10.26	7.59	0.87
	RL	31	0.02	0.01	29.39	9.43		0.00
	COMPARISON	90	-		29.00	8.95		-
MATH TOTAL	MM	44	15.18	5.24	75.05	20.47	14.92	1.02
	RL	31	1.59	0.50	61.23	19.36		0.11
	COMPARISON	90	-		58.82	18.43		-

CTBS	Treatment Group	N	Treatment Effect	(t) 160df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	46	3.74	2.34	29.63	8.82	8.26	0.45
	RL	32	-0.24	-0.13	25.88	8.96		-0.03
	COMPARISON	90	-		26.32	9.09		-
CONCEPTS	MM	46	-0.13	-0.15	12.80	5.32	4.36	-0.03
	RL	32	-0.08	-0.09	12.84	5.10		-0.02
	COMPARISON	90	-		12.72	4.95		-
APPLICATIONS	MM	46	1.36	1.50	11.83	6.08	4.72	0.29
	RL	32	0.97	0.97	11.41	5.84		0.21
	COMPARISON	90	-		10.27	5.22		-
MATH TOTAL	MM	46	4.97	1.76	54.26	17.82	14.62	0.34
	RL	32	0.65	0.21	50.13	17.53		0.04
	COMPARISON	90	-		49.31	16.81		-

Table 4-53

Longitudinal Analysis for GRADE 2 to GRADE 5: CAI VS COMPARISONS.

PERIOD = YEAR 1 to YEAR 4.

Posttest= CST AND CTBS Subject = READING.

Treatment effects and posttest means by treatment group,
Schools = 2-4 vs 5-6.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	150df	$\bar{X}$	SD	SD	T.E.
PART A	MM	43	-0.27	-0.16	40.93	9.52	8.07	-0.03
	RL	30	0.74	0.42	41.93	7.27		0.09
	COMPARISON	85	-		40.01	8.64		-
PART B	MM	43	-0.06	-0.03	37.35	10.92	9.99	-0.01
	RL	30	1.09	0.50	38.63	9.83		0.11
	COMPARISON	85	-		36.18	10.93		-
READING	MM	43	-0.33	-0.10	78.28	19.26	16.92	-0.02
TOTAL	RL	30	1.83	0.50	80.56	16.19		0.11
	COMPARISON	85	-		76.19	18.60		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	160df	$\bar{X}$	SD	SD	T.E.
VOCABULARY	MM	47	-0.58	-0.49	19.30	8.49	6.16	-0.09
	RL	32	-0.25	-0.19	19.75	8.40		-0.04
	COMPARISON	89	-		18.39	7.40		-
COMPREHENSION	MM	47	-1.45	-1.09	19.30	9.50	6.96	-0.21
	RL	32	-1.87	-1.28	19.31	9.19		-0.27
	COMPARISON	89	-		19.33	7.97		-
READING	MM	47	-2.02	-0.89	38.60	17.26	11.95	-0.17
TOTAL	RL	32	-2.12	-0.85	39.06	16.75		-0.18
	COMPARISON	89	-		37.72	14.21		-

Table 4-54

Longitudinal Analysis for GRADE 2 to GRADE 5: CAI VS COMPARISONS.

PERIOD = YEAR 1 to YEAR 4.

Posttest= CST AND CTBS Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 2-4 vs 5-6.

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CST	Group	N	Effect	150df	$\bar{X}$	SD	SD	T.E.
PART A	MM	43	0.74	0.50	42.12	6.61	7.53	0.10
	RL	30	3.66	2.24	45.13	8.39		0.49
	COMPARISON	85	-		40.24	8.98		-
PART B	MM	43	0.76	0.50	39.21	7.26	7.63	0.10
	RL	30	2.65	1.60	41.27	7.60		0.35
	COMPARISON	85	-		37.71	9.23		-
LANGUAGE	MM	43	1.51	0.55	81.33	12.54	13.79	0.11
TOTAL	RL	30	6.31	2.11	86.40	14.42		0.46
	COMPARISON	85	-		77.94	17.09		-

	Treatment		Treatment	(t)	Posttest		Residual	Standardized
CTBS	Group	N	Effect	160df	$\bar{X}$	SD	SD	T.E.
SPELLING	MM	47	-0.36	-0.27	32.94	7.93	6.98	-0.05
	RL	32	-0.88	-0.61	32.91	7.93		-0.13
	COMPARISON	89	-		32.34	8.19		-
MECHANICS	MM	47	0.59	0.77	11.43	4.42	4.01	0.15
	RL	32	0.50	0.59	11.53	3.88		0.12
	COMPARISON	89	-		10.38	4.66		-
EXPRESSION	MM	47	-0.18	-0.18	16.58	6.21	5.18	-0.03
	RL	32	0.41	0.38	17.25	6.67		0.08
	COMPARISON	89	-		15.44	6.15		-
LANGUAGE	MM	47	0.05	0.02	60.94	16.53	13.17	0.00
TOTAL	RL	32	0.02	0.01	61.69	15.06		0.00
	COMPARISON	89	-		58.15	16.55		-

Discussion for Grades 2-5

Mathematics. The mathematics data for the grades 2-5 longitudinal group are remarkably consistent. Table 4-55 presents an overview of each of the one-year studies and each of the longitudinal studies we have just seen. Entries in the table are treatment effects in terms of residual standard deviations. Statistically significant effects are starred. In each cell the first figure is for the CST total, and the remainder are for the CTBS subtests: computation, concepts, and applications.

Consistently, the CST figures indicate that the mathematics CAI curriculum is doing what it was designed to do: viz., give students drill-and-practice in mathematics computation. If you compare results of the one-year study at grade 4 with the two-year study ending at grade 4, results for one year are .63 and for two years .99 of a standard deviation. At the fifth grade the figures for one, two, and three years of MM CAI are .76, 1.18 and 1.17 of a standard deviation. Students are learning the mathematics CAI curriculum and are demonstrating superior performance when tested on that curriculum. The treatment effects for the MM group when compared with cohort controls or students in comparison schools also demonstrate superior performance.

The CTBS computation figures also demonstrate that the CAI mathematics drill-and-practice curriculum can produce significant effects on a standardized test. When the MM group is contrasted with the RL group, significant treatment effects for one year of CAI are .28 and .52, for two years .59 and .57, and for three years .79 of a standard deviation. Students with three years of mathematics CAI function at .70 of a standard deviation higher than students in the same schools without CAI and .45 of a standard deviation higher than students in comparison schools.

Table 4-55

Treatment Effects Given in Standard Deviations for Mathematics Scores for the Longitudinal CAI Cohort, Grades 2-5

	Grade 2	Grade 3	Grade 4	Grade 5	
	MM vs M (N=220+)	MM vs ML (N=190+)	MM vs RL (N=265+)	MM vs RL (N=145+)	
CST	.08	.67*	.63*	.76*	
COMPUTATION	.35*	.38*	.28*	.52*	
CONCEPTS &	.33*	-.03	.06	-.10	
APPLICATIONS		.04	.10	-.16	
		MM vs RL (N = 87+)			
CST				1.17*	
COMPUTATION				.79*	
CONCEPTS &				-.10	
APPLICATIONS				-.05	
		MM vs RL (N = 134+)			
CST			.99*		
COMPUTATION			.59*		
CONCEPTS &			.21		
APPLICATIONS			.36		
			MM vs RL (N = 98+)		
CST				1.18*	
COMPUTATION				.57*	
CONCEPTS &				-.21	
APPLICATIONS				-.20	
		MM & RL CAI vs Cohort Controls (N = 198+)			
				MM	RL
CST				1.26*	.46*
COMPUTATION				.70*	.08
CONCEPTS &				.18	.11
APPLICATIONS				.28	.22
	MM & RL CAI vs Comparison School Students (N = 165+)				
				MM	RL
CST				1.02*	.11
COMPUTATION				.45*	-.03
CONCEPTS &				-.03	-.02
APPLICATIONS				.29	.21

*P < .05

With regard to concepts and applications, the only statistically significant treatment effect is in grade 2 when that portion of the test is read to students. In grades 3-5 when the word problems of the concepts and applications subtests are not read to students, there are no statistically significant treatment effects. The MM condition may help students with the mathematics of the problems while the RL condition may be helping with the reading. Some slight evidence for that exists when CAI students are compared to their cohort controls or comparison students. In those comparisons, the MM and RL students perform in very similar ways.

Reading. Table 4-56 presents an overview of the reading results for each of the one-year studies and each of the reported longitudinal studies for the grades 2-5 cohort. Reading results are mixed. Even for the CSTs based on the reading curriculum, the RL group's treatment effects are statistically significant in grade 4 but not in grade 5 of the one-year studies. For the longitudinal studies comparing the RL and MM groups, one two-year study found statistically significant treatment effects while the three-year study and an earlier less-appropriate two-year study did not. When RL students are contrasted with their cohort controls, the RL students score a statistically significant .56 of a standard deviation higher, but when they are contrasted with students in comparison schools, there is no significant difference.

For the CTBS data, the treatment effect for reading comprehension in the grade 4 one-year study is the only statistically significant treatment effect with two exceptions. Significant treatment effects in reading vocabulary are found for both the RL and MM students when they are contrasted with their cohort controls. Overall, the results are unclear. Treatment effects are more likely to be positive than negative, but no strong pattern emerges.

Table 4-56

Treatment Effects Given in Standard Deviations for Reading Scores for the Longitudinal CAI Cohort, Grades 2-5

Grade 2	Grade 3	Grade 4	Grade 5	
MM vs M N=220+) →	ML vs MM N=199+) →	RL vs MM N=267+) →	RL vs MM N=171+) →	
CST	-.15	.34*	.20	
VOCABULARY	-.16	.25	.23	
COMPREHENSION	-.29	.26*	.31	
	RL vs MM (N = 85+) →			
CST			.31	
VOCABULARY			-.04	
COMPREHENSION			.24	
	RL vs MM (N = 137+) →			
CST		.16		
VOCABULARY		.04		
COMPREHENSION		.02		
		RL vs MM (N = 106) →		
CST			.73*	
VOCABULARY			.14	
COMPREHENSION			.27	
	RL and MM vs Cohort Controls (N = 193+) →			
			RL	MM
CST			.56*	.23
VOCABULARY			.41*	.34*
COMPREHENSION			.20	.17
RL and MM vs Comparison School Students (N = 158+) →				
			RL	MM
CST			.11	-.02
VOCABULARY			-.04	-.09
COMPREHENSION			-.27	-.21

*P < .05

Language. Table 4-57 presents an overview of the language results for each of the one-year studies and each of the reported longitudinal studies for the grades 2-5 cohort. The CST results are consistent and are statistically significant. The language CAI curriculum is giving students drill-and-practice on a skill in which they can then demonstrate superior performance.

A demonstration of that skill on the CTBS subtests is much more elusive. Only a one-year study at grade 4 produced any statistically significant treatment effects. That cell also contains the largest number of students.

There appears to be some consistency in the mechanics and expression subtests. Although the treatment effects are not statistically significant, they are uniformly positive and sometimes quite high. If we look at mechanics, for instance, the three one-year studies show treatment effects of .10, .41*, and .21 of a standard deviation, while the three within-CAI longitudinal studies show effects of .40, .34 and .22 of a standard deviation.

The CAI treatment consisting of one session of reading and one of language contained the same amount of CAI time as the treatment calling for two sessions of mathematics. However, the RL group received only half as much of the CAI reading curriculum or the CAI language curriculum as MM students received of the mathematics curriculum. Table 4-58 gives a comparison of the treatment effects for language mechanics and mathematics computation. Very roughly, the figures for the treatment effects in language mechanics appear to be about half the size of the effects for computation. This could be related to the amount of CAI experienced by students, with 20 minutes per day in mathematics superior to 10 minutes in language for producing treatment effects. There has been fairly consistent evidence that greater exposure produces greater results.

Table 4-57

Treatment Effects Given in Standard Deviations for Language Scores for the Longitudinal CAI Cohort, Grades 2-5

	Grade2	Grade 3	Grade 4	Grade 5
	MM vs M N=220+) →	ML vs MM (N=199+) →	RL vs MM (N=267+) →	RL vs MM (N=171) →
CST	--	.46*	.65*	.56*
SPELLING	--	-.12	.03	-.09
MECHANICS	—	.10	.41*	.21
EXPRESSION	--	.01	.33*	.33
		RL vs MM (N = 85+) →		
CST				.71*
SPELLING				.06
MECHANICS				.40
EXPRESSION				.2[illegible]
		RL vs MM (N = 137+) →		
CST			.59*	
SPELLING			-.22	
MECHANICS			.34	
EXPRESSION			.15	
			RL vs MM (N = 106) →	
CST				1.14*
SPELLING				.02
MECHANICS				.22
EXPRESSION				.13
		RL and MM vs Cohort Controls (N = 193+) →		RL MM
CST				1.06* .45*
SPELLING				.20 .20
MECHANICS				.49 .47
EXPRESSION				.18 .16
	RL and MM vs Comparison School Students (N = 158+) →			RL MM
CST				.46* .11
SPELLING				-.13 -.05
MECHANICS				.12 .15
EXPRESSION				.08 -.03

*P < .05

Table 4-58

A Comparison of the Treatment Effects for Language Mechanics (10 min/day of instruction and Mathematics Computation (20 min/day of instruction)

	Grade 3	Grade 4	Grade 5
One-year Studies	├──────→	├──────→	├──────→
LANGUAGE MECHANICS	.10	.41*	.21
MATH COMPUTATION	.38	.28*	52*
Longitudinal	├──────	──────	──────→
LANGUAGE MECHANICS (N = 20 items)			.40
MATH COMPUTATION (N = 48 items)			.79*
	├──────	──────→	
LANGUAGE MECHANICS		.34	
MATH COMPUTATION		59*	
		├──────	──────→
LANGUAGE MECHANICS			.22
MATH COMPUTATION			.57*

* $P < .05$

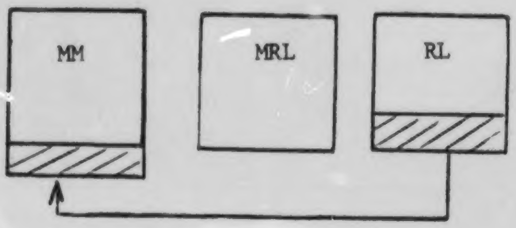
The Grade 4 to Grade 6 Longitudinal Study

The grade 4 to grade 6 longitudinal study is summarized as follows:

Grade 4		Grade 5		Grade 6
MM	→	MM	→	MM
MRL	→	MRL	→	MRL
RL	→	RL	→	RL

In year 1, the fourth graders were randomly assigned to one of the three treatment conditions: two sessions of mathematics CAI daily (MM), one session of reading and one of language daily (RL), or a combination of one session of mathematics daily with a second session which alternated between reading and language. The same curriculums were kept for three consecutive years of the study. As it has been pointed out in the one-year study, there are three levels of treatment conditions with regard to mathematics and reading and language arts. The persistence of the same treatment condition was expected to magnify the difference in the treatment effects.

One serious problem developed. Some non-readers, non-English-speaking or limited-English-speaking students were randomly assigned to the RL or MRL treatments. At the onset of the CAI lab in year 1, it became obvious that the pure reading and language condition (RL) was impossible for them to follow and to a lesser extent so was the MRL condition. The CAI coordinators moved non-English-speaking students to mathematics but kept doubtful students in their original assignments for a month to six weeks. If no progress was made, they then reassigned students to the MM treatment. The inability of the reading and language curriculums to adjust to the needs of students of low reading ability caused problems for the research design. Let us picture the grade 4 conditions as follows:



Originally there were three randomly assigned groups of students. Because of the random assignment the groups were about the same size and had students of about the same ability level. When non-readers or non-English speaking students were removed from the RL group, the RL group became smaller and developed higher pretest and posttest means as a result. Although such students were reassigned to the MM group after making no progress in reading or language, the computer logs showed them as receiving mathematics, reading, and language CAI, i.e., as actual MRL students.

Attrition affected this longitudinal group more heavily than others because of the implementation of the LAUSD desegregation plan. All sixth-grade students from school 1 and 25 students from school 3 were moved to schools where the CAI program could not be implemented. Differential attrition rates operating on the groups over three years further complicated the longitudinal design for grades 4-6. The original fourth-grade pretest means of the MM and MRL groups decreased with attrition over three years, while the pretest means of the RL group increased with attrition.

Results for the Longitudinal Data, Grades 4-6

Six sets of analyses will be presented in this section. We will present the following regressions:

(1) grade 4 (posttests) to grade 6: within CAI
(2) grade 4 (posttests) to grade 5: within CAI
(3) grade 4 (pretests) to grade 5: within CAI
(4) grade 5 (pretests) to grade 6: within CAI
(5) CAI vs. cohort controls
(6) CAI vs. comparison schools

The first four analyses involve only CAI students. The last two analyses compare CAI students with cohort controls in their own schools one year later and with non-CAI students in comparison schools.

Grades 4-6. Table 4-59 presents the results for the mathematics regression analyses. For the CST data, the treatment effects for the MM and MRL groups are statistically significant. On the average, MM students answered 11.36 more questions correctly than did the RL group and are almost one standard deviation above them in CST performance in mathematics. For the CTBS data, statistically significant treatment effects are found in computation and math total for both MM and MRL students. The MRL students also performed significantly better than the RL group in applications.

Table 4-60 presents the reading results. None of the treatment effects on the CST is significant and only the treatment effect for the MRL group on the CTBS vocabulary subtest is statistically significant.

Table 4-59

Longitudinal Analysis for GRADE 4 to GRADE 6.

PERIOD = YEAR 1 to YEAR 3.

Posttest= CST AND CTBS (from CTBS) Subject = MATHEMATICS.

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 62df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	34	6.00	2.75	37.85	9.75	6.89	0.87
	MRL	34	3.71	1.75	35.50	10.21		0.54
	RL	26	-		35.12	8.69		-
PART B	MM	34	5.36	2.97	27.47	9.90	5.69	0.94
	MRL	34	5.07	2.89	26.32	9.59		0.89
	RL	26	-		26.12	6.15		-
MATH TOTAL	MM	34	11.36	3.05	65.32	18.93	11.75	0.97
	MRL	34	8.78	2.43	61.82	19.33		0.75
	RL	26	-		61.23	14.03		-

CTBS	Treatment Group	N	Treatment Effect	(t) 62df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATIONS	MM	32	3.42	2.02	32.16	9.59	5.31	0.64
	MRL	35	3.99	2.47	30.34	8.83		0.75
	RL	27	-		32.07	8.67		-
CONCEPTS	MM	32	0.82	0.88	14.00	4.74	2.90	0.28
	MRL	35	0.47	0.53	13.11	4.71		0.16
	RL	27	-		15.48	3.52		-
APPLICATIONS	MM	32	2.14	1.82	12.53	5.65	3.68	0.58
	MRL	35	2.39	2.13	11.91	6.08		0.65
	RL	27	-		13.33	3.56		-
MATH TOTAL	MM	32	6.37	2.48	58.69	18.17	8.04	0.79
	MRL	35	6.85	2.80	55.37	17.40		0.85
	RL	27	-		60.89	14.32		-

Table 4-60

Longitudinal Analysis for GRADE 4 to GRADE 6.

PERIOD = YEAR 1 to YEAR 3.

Posttest= CST AND CTBS (from CTBS)   Subject = READING.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 59df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	30	-		36.50	10.39	7.13	-
	MRL	34	4.38	2.07	39.79	9.44		0.61
	RL	29	3.23	1.40	42.72	7.65		0.45
PART B	MM	30	-		31.33	9.95	6.88	-
	MRL	34	0.61	0.30	31.62	12.40		0.09
	RL	29	2.04	0.92	36.03	9.97		0.30
READING TOTAL	MM	30	-		67.83	19.49	12.52	-
	MRL	34	4.99	1.34	71.41	20.95		0.40
	RL	29	5.28	1.30	78.76	15.75		0.42

CTBS	Treatment Group	N	Treatment Effect	(t) 60df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	31	-		21.19	8.42	4.65	-
	MRL	35	3.34	2.47	23.63	8.47		0.72
	RL	27	2.71	1.79	26.85	7.84		0.58
COMPREHENSION	MM	31	-		24.84	9.71	5.01	-
	MRL	35	-1.00	-0.69	23.43	10.03		-0.20
	RL	27	-1.22	-0.75	27.78	9.26		-0.24
READING TOTAL	MM	31	-		46.03	17.32	8.24	-
	MRL	35	2.34	0.98	47.06	17.74		0.28
	RL	27	1.49	0.56	54.63	16.31		0.18

Table 4-61 presents the language results. Treatment effects on the CST totals are statistically significant for both the RL and MRL groups. The RL group, with almost 7 more questions correct on the average than the MM group, is about three-quarters of a standard deviation above them in performance on the language CST. Although treatment effects on the CTBS are all positive, none is significant.

Table 4-61

Longitudinal Analysis for GRADE 4 to GRADE 6.

PERIOD = YEAR 1 to YEAR 3.

Posttest= CST AND CTBS (from CTBS)   Subject = LANGUAGE.

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 59df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	30	-		39.83	7.84	5.32	-
	MRL	34	3.25	2.05	42.85	6.58		0.61
	RL	29	4.37	2.53	45.90	6.12		0.82
PART B	MM	30	-		34.97	7.38	4.57	-
	MRL	34	2.01	1.48	37.18	6.32		0.44
	RL	29	2.39	1.62	39.97	5.12		0.52
LANGUAGE TOTAL	MM	30	-		74.80	14.36	8.94	-
	MRL	34	5.26	1.98	80.03	12.28		0.59
	RL	29	6.76	2.33	85.86	10.71		0.76

CTBS	Treatment Group	N	Treatment Effect	(t) 60df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
SPELLING	MM	31	-		33.42	9.19	5.32	-
	MRL	35	2.02	1.31	35.17	8.99		0.38
	RL	27	1.15	0.66	38.04	7.94		0.22
MECHANICS	MM	31	-		11.42	4.19	2.98	-
	MRL	35	0.66	0.76	11.97	4.32		0.22
	RL	27	0.26	0.26	13.52	2.97		0.09
EXPRESSION	MM	31	-		19.00	7.23	3.69	-
	MRL	35	0.52	0.47	18.97	7.75		0.14
	RL	27	0.81	0.67	22.74	6.43		0.22
LANGUAGE TOTAL	MM	31	-		63.84	18.27	9.15	-
	MRL	35	3.19	1.20	66.11	19.37		0.35
	RL	27	2.21	0.74	74.30	15.14		0.24

Grades 4-5 (from CTBS, grade 4). Table 4-62 presents the mathematics results. For the CST data, the treatment effects for the MM and MRL groups are all statistically significant. With 17 more questions correct on the average than the RL group, the MM group is about 1.4 standard deviations above the RL group in performance on the mathematics CST. On the CTBS, treatment effects in computation and math total are statistically significant. The MM group answered 4.15 more computation questions correctly than the RL group on the average and is about three-quarters of a standard deviation above them in performance on mathematics computation.

Table 4-63 presents the reading results. None of the treatment effects for the CST or CTBS data is statistically significant.

Table 4-64 presents the language results. For the CST data, treatment effects for the RL group are statistically significant. The RL group on the average answered 6.14 more questions correctly than the MM group and is about .59 of a standard deviation above them in performance on the language CST. For the CTBS data, none of the treatment effects is statistically significant.

Table 4-62

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from CTBS) Subject = MATHEMATICS

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 133df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	56	9.59	6.61	33.66	11.75	6.83	1.40
	MRL	54	5.32	3.74	28.50	12.41		0.78
	RL	50	-		27.40	10.09		-
PART B	MM	56	7.60	5.57	30.34	9.22	6.42	1.18
	MRL	54	4.82	3.61	27.06	10.90		0.75
	RL	50	-		25.24	8.26		-
MATH TOTAL	MM	56	17.19	6.67	64.00	20.39	12.13	1.42
	MRL	54	10.14	4.01	55.56	22.77		0.84
	RL	50	-		52.64	17.46		-

CTBS	Treatment Group	N	Treatment Effect	(t) 137df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	53	4.15	3.66	27.15	9.00	5.49	0.76
	MRL	57	3.29	2.98	24.98	9.16		0.60
	RL	53	-		24.51	9.36		-
CONCEPTS	MM	53	0.68	1.23	12.43	3.75	2.67	0.25
	MRL	57	-0.17	-0.31	11.54	4.09		-0.06
	RL	53	-		12.79	4.31		-
APPLICATIONS	MM	53	0.43	0.58	9.79	4.99	3.59	0.12
	MRL	57	1.00	1.39	10.00	4.88		0.28
	RL	53	-		10.40	5.14		-
MATH TOTAL	MM	53	5.26	2.97	49.38	14.92	8.59	0.61
	MRL	57	4.13	2.39	46.53	16.45		0.48
	RL	53	-		47.70	16.59		-

Table 4-63

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from CTBS) Subject = READING

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 129df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	53	-		36.75	10.43	6.40	-
	MRL	54	-0.50	-0.38	36.41	10.80		-0.08
	RL	51	1.98	1.44	42.57	7.42		0.31
PART B	MM	53	-		31.53	11.87	7.64	-
	MRL	54	-1.18	-0.74	30.70	12.98		-0.15
	RL	51	1.01	0.62	37.65	10.57		0.13
READING TOTAL	MM	53	-		68.28	21.56	12.77	-
	MRL	54	-1.68	-0.63	67.11	22.74		-0.13
	RL	51	2.99	1.09	80.22	17.47		0.23

CTBS	Treatment Group	N	Treatment Effect	(t) 127df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
VOCABULARY	MM	48	-		19.65	6.81	4.39	-
	MRL	56	0.11	0.13	19.14	8.76		0.03
	RL	51	0.09	0.10	22.02	8.23		0.02
COMPREHENSION	MM	48	-		21.13	7.94	5.16	-
	MRL	56	-0.82	-0.77	19.63	9.32		-0.16
	RL	51	-0.20	-0.18	23.16	9.23		-0.04
READING TOTAL	MM	48	-		40.77	13.61	7.95	-
	MRL	56	-0.71	-0.43	38.77	17.39		-0.09
	RL	51	-0.11	-0.06	45.18	16.60		-0.01

Table 4-64

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from CTBS)   Subject = LANGUAGE

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 129df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	53	-		39.92	9.61	6.64	-
	MRL	54	1.84	1.33	41.81	9.77		0.28
	RL	51	3.61	2.54	46.63	7.76		0.54
PART B	MM	53	-		37.64	7.77	5.63	-
	MRL	54	0.01	0.01	37.52	10.01		0.00
	RL	51	2.53	2.09	43.22	8.49		0.45
LANGUAGE TOTAL	MM	53	-		77.57	16.05	10.32	-
	MRL	54	1.85	0.86	79.33	18.44		0.18
	RL	51	6.14	2.77	89.84	15.23		0.59

CTBS	Treatment Group	N	Treatment Effect	(t) 127df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	48	-		32.71	7.08	5.17	-
	MRL	56	-0.31	-0.29	31.89	9.05		-0.06
	RL	51	1.37	1.24	36.39	8.65		0.26
MECHANICS	MM	48	-		10.65	3.71	2.88	-
	MRL	56	0.90	1.52	10.89	4.92		0.31
	RL	51	0.28	0.45	11.86	3.91		0.10
EXPRESSION	MM	48	-		17.52	6.29	3.92	-
	MRL	56	-1.13	-1.39	15.96	6.73		-0.29
	RL	51	-1.57	-1.89	17.96	7.10		-0.40
LANGUAGE TOTAL	MM	48	-		60.88	14.71	8.78	-
	MRL	56	-0.53	-0.29	58.75	18.60		-0.06
	RL	51	0.07	0.04	66.21	17.74		0.01

Grades 4-5 (from ITBS, grade 4). Table 4-65 presents the mathematics results when the regression analyses use the ITBS data as pretests. For the CST data, treatment effects for the MM group are statistically significant. The MM group answered 15.46 more questions correctly on the average than the RL group and is more than one standard deviation above that group in performance on the mathematics CST. Treatment effects for the MM group are also statistically significant in CTBS computation and CTBS mathematics total. In computation the MM group answered 3.77 more questions correctly than the RL group and is almost two-thirds of a standard deviation above them in performance.

Table 4-66 presents the reading results. For the CST total, the treatment effect for the RL group is statistically significant, and that group is almost half a standard deviation above the MM group in performance on the reading CST. None of the treatment effects for the CTBS data is statistically significant.

Table 4-67 presents the language results. Again the RL group's treatment effect on the CST is statistically significant, but the MRL group's is not. On the CTBS only the treatment effect for the RL group in spelling is statistically significant.

Table 4-65

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from ITBS)   Subject = MATHEMATICS

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 85df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	45	8.57	4.67	34.04	11.91	8.23	1.04
	MRL	49	2.52	1.39	27.86	12.30		0.31
	RL	46	-		27.83	10.18		-
PART B	MM	45	6.89	4.47	30.47	9.33	6.92	0.99
	MRL	49	3.02	1.98	26.63	10.87		0.44
	RL	46	-		25.37	8.48		-
MATH TOTAL	MM	45	15.46	4.94	64.51	20.61	14.05	1.10
	MRL	49	5.54	1.79	54.49	22.58		0.39
	RL	46	-		53.20	17.74		-

CTBS	Treatment Group	N	Treatment Effect	(t) 90df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	44	3.77	2.92	26.80	8.89	5.97	0.63
	MRL	51	1.50	1.20	24.76	8.78		0.25
	RL	49	-		24.86	9.04		-
CONCEPTS	MM	44	0.57	0.96	12.64	3.66	2.75	0.21
	MRL	51	-0.40	-0.69	11.51	4.10		-0.15
	RL	49	-		12.65	4.29		-
APPLICATIONS	MM	44	0.25	0.32	10.00	5.00	3.68	0.07
	MRL	51	0.46	0.59	10.14	5.02		0.12
	RL	49	-		10.61	5.26		-
MATH TOTAL	MM	44	4.60	2.23	49.43	15.19	9.53	0.48
	MRL	51	1.56	0.78	46.41	16.31		0.16
	RL	49	-		48.12	16.52		-

Table 4-66

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from ITBS) Subject = READING

Treatment effects and posttest means by treatment group,
Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 79df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	45	-		36.53	10.61	7.23	-
	MRL	50	-0.80	-0.51	36.16	10.56		-0.11
	RL	49	4.04	2.49	42.57	7.56		0.56
PART B	MM	45	-		31.60	12.07	8.44	-
	MRL	50	-2.07	-1.13	30.32	12.74		-0.25
	RL	49	3.14	1.66	37.98	10.67		0.37
READING TOTAL	MM	45	-		68.13	21.91	14.46	-
	MRL	50	-2.88	-0.91	66.48	22.15		-0.20
	RL	49	7.18	2.22	80.55	17.74		0.50

CTBS	Treatment Group	N	Treatment Effect	(t) 78df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	42	-		18.93	6.15	4.64	-
	MRL	51	0.37	0.36	19.47	8.53		0.08
	RL	49	0.38	0.37	21.57	8.16		0.08
COMPREHENSION	MM	42	-		20.93	8.00	4.98	-
	MRL	51	-1.42	-1.31	19.67	9.19		-0.29
	RL	49	-0.33	-0.29	22.92	9.04		-0.07
READING TOTAL	MM	42	-		39.86	13.09	8.15	-
	MRL	51	-1.06	-0.59	39.14	17.09		-0.13
	RL	49	0.05	0.03	44.49	16.34		0.01

Table 4-67

Longitudinal Analysis for GRADE 4 to GRADE 5

PERIOD = YEAR 1 TO YEAR 2

Posttest= CST & CTBS (from ITBS)   Subject = LANGUAGE

Treatment effects and posttest means by treatment group, Schools = 1-4.

CST	Treatment Group	N	Treatment Effect	(t) 79df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	45	-		39.09	10.74	7.63	-
	MRL	50	2.00	1.20	41.58	9.95		0.26
	RL	49	4.84	2.83	46.41	7.84		0.63
PART B	MM	45	-		37.20	8.16	6.40	-
	MRL	50	-0.38	-0.27	37.12	10.05		-0.06
	RL	49	3.99	2.79	43.31	8.68		0.62
LANGUAGE TOTAL	MM	45	-		76.29	17.48	12.00	-
	MRL	50	1.62	0.62	78.70	18.59		0.14
	RL	49	8.83	3.29	89.71	15.52		0.74

CTBS	Treatment Group	N	Treatment Effect	(t) 78df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
SPELLING	MM	42	-		32.57	7.55	5.37	-
	MRL	51	-1.37	-1.17	31.69	9.07		-0.26
	RL	49	2.46	2.06	36.47	8.73		0.46
MECHANICS	MM	42	-		10.36	3.98	3.12	-
	MRL	51	0.89	1.30	11.12	4.84		0.29
	RL	49	1.05	1.51	12.08	3.93		0.34
EXPRESSION	MM	42	-		17.36	6.49	3.83	-
	MRL	51	-1.53	-1.83	15.86	6.58		-0.40
	RL	49	-0.47	-0.55	18.35	7.26		-0.12
LANGUAGE TOTAL	MM	42	-		60.29	15.66	9.11	-
	MRL	51	-2.01	-1.01	58.67	18.28		-0.22
	RL	49	3.04	1.50	66.90	18.09		0.33

Grades 5-6. Table 4-68 presents the mathematics results for the CAI cohort in grades 5-6. Treatment effects on the mathematics CST total are statistically significant for the MM group but not for the MRL group. For the CTBS data, none of the treatment effects is significant.

Table 4-69 presents the reading results. None of the treatment effects is significant.

Table 4-70 presents the language results. For the CST total, the treatment effect for the RL group is statistically significant. For the CTBS data, none of the treatment effects is significant.

Table 4-68

Longitudinal Analysis for GRADE 5 to GRADE 6

PERIOD = YEAR 2 to YEAR 3

Posttest= CST & CTBS (from ITBS)   Subject = MATHEMATICS

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 85df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	37	3.22	1.76	39.08	9.96	6.30	0.51
	MRL	44	2.20	1.27	35.66	10.73		0.35
	RL	28	-		25.21	8.67		-
PART B	MM	37	3.99	2.35	29.08	10.49	5.85	0.68
	MRL	44	3.15	1.96	25.70	10.44		0.54
	RL	28	-		25.96	7.02		-
MATH TOTAL	MM	37	7.20	2.24	68.16	19.70	11.11	0.65
	MRL	44	5.35	1.75	61.37	20.70		0.48
	RL	28	-		61.18	14.97		-

CTBS	Treatment Group	N	Treatment Effect	(t) 94df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
COMPUTATION	MM	37	2.01	1.06	33.19	9.71	7.08	0.28
	MRL	44	1.62	0.89	30.95	8.73		0.23
	RL	33	-		31.79	8.32		-
CONCEPTS	MM	37	-0.08	-0.11	14.14	4.94	2.97	-0.03
	MRL	44	-0.64	-0.84	12.96	4.81		-0.22
	RL	33	-		15.24	3.58		-
APPLICATIONS	MM	37	0.80	0.73	13.08	5.99	4.08	0.20
	MRL	44	1.48	1.41	12.16	6.37		0.36
	RL	33	-		12.94	5.50		-
MATH TOTAL	MM	37	2.73	0.91	60.41	18.83	11.27	0.24
	MRL	44	2.46	0.85	55.82	18.06		0.22
	RL	33	-		59.97	14.24		-

Table 4-69

Longitudinal Analysis for GRADE 5 to GRADE 6

PERIOD = YEAR 2 TO YEAR 3

Posttest= CST & CTBS (from ITBS) Subject = READING

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 79df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	33	-		37.15	11.62	6.60	-
	MRL	42	0.84	0.47	38.41	10.14		0.13
	RL	30	1.42	0.76	41.53	8.29		0.21
PART B	MM	33	-		31.09	11.38	6.73	-
	MRL	42	0.34	0.19	30.79	12.56		0.05
	RL	30	2.39	1.26	34.93	10.86		0.35
READING TOTAL	MM	33	-		68.24	21.96	11.95	-
	MRL	42	1.18	0.36	69.19	22.13		0.10
	RL	30	3.80	1.13	76.47	17.59		0.32

CTBS	Treatment Group	N	Treatment Effect	(t) 78df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	35	-		21.94	8.43	5.97	-
	MRL	40	2.84	1.77	22.98	8.53		0.48
	RL	31	1.70	1.00	25.84	8.94		0.28
COMPREHENSION	MM	35	-		25.60	10.10	6.77	-
	MRL	40	-0.58	-0.32	23.65	10.63		-0.09
	RL	31	-1.62	-0.84	26.42	9.72		-0.24
READING TOTAL	MM	35	-		47.54	17.74	11.73	-
	MRL	40	2.26	0.72	46.63	19.48		0.19
	RL	31	0.09	0.03	52.26	18.06		0.01

Table 4-70

Longitudinal Analysis for GRADE 5 to GRADE 6

PERIOD = YEAR 2 TO YEAR 3

Posttest= CST & CTBS (from ITBS)   Subject = LANGUAGE

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 79df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	33	-		40.46	8.33	5.31	-
	MRL	42	0.68	0.47	42.10	7.24		0.13
	RL	30	2.90	1.94	45.33	6.19		0.55
PART B	MM	33	-		35.49	7.63	4.70	-
	MRL	42	1.14	0.90	36.33	6.81		0.24
	RL	30	2.37	1.79	39.53	5.41		0.50
LANGUAGE TOTAL	MM	33	-		75.94	15.41	9.27	-
	MRL	42	1.83	0.72	78.43	13.56		0.20
	RL	30	5.27	2.01	84.87	11.05		0.57

CTBS	Treatment Group	N	Treatment Effect	(t) 78df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
SPELLING	MM	35	-		33.86	9.31	6.53	-
	MRL	40	0.78	0.45	34.45	9.87		0.12
	RL	31	-0.36	-0.20	37.42	8.72		-0.06
MECHANICS	MM	35	-		11.94	4.11	3.06	-
	MRL	40	0.82	1.00	11.90	4.15		0.27
	RL	31	0.55	0.64	13.13	3.67		0.18
EXPRESSION	MM	35	-		19.91	7.71	5.11	-
	MRL	40	0.75	0.55	19.03	7.56		0.15
	RL	31	0.18	0.12	21.71	7.11		0.04
LANGUAGE TOTAL	MM	35	-		65.71	18.65	12.20	-
	MRL	40	2.35	0.72	65.38	20.05		0.19
	RL	31	0.36	0.11	72.26	17.40		0.03

Grades 4-6: CAI vs cohort controls. Table 4-71 presents the mathematics results when CAI students are compared to cohort controls in the same schools one year later without CAI. For the CST data, all of the treatment effects are statistically significant, even those for the RL group. For the CTBS data, none of the treatment effects is significant.

Table 4-72 presents the reading results. None of the treatment effects is statistically significant.

Table 4-73 presents the language results. For the CST total, the treatment effects for the RL and MRL groups are statistically significant. The adjusted mean score for the RL group is 7.75 items higher than the adjusted mean for the cohort controls, and the RL group is two-thirds of a standard deviation higher in performance on the language CST. For the CTBS data, none of the treatment effects is statistically significant.

Table 4-71

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COHORTS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS) Subject = MATHEMATICS

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 168df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	27	8.36	5.09	38.37	9.06	7.44	1.12
	MRL	27	5.52	3.27	35.11	10.11		0.74
	RL	23	3.81	2.13	35.61	8.24		0.51
	COHORT	102	-		29.10	8.60		-
PART B	MM	27	6.28	4.33	27.48	9.09	6.58	0.95
	MRL	27	5.46	3.65	26.26	9.87		0.83
	RL	23	3.75	2.38	26.52	6.16		0.57
	COHORT	102	-		20.67	7.08		-
MATH TOTAL	MM	27	14.64	5.02	65.85	17.56	13.22	1.11
	MRL	27	10.98	3.66	61.37	19.45		0.83
	RL	23	7.56	2.39	61.13	13.50		0.57
	COHORT	102	-		49.77	15.08		-

CTBS	Treatment Group	N	Treatment Effect	(t) 170df	Posttest X̄	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	25	0.62	0.37	32.00	9.15	7.37	0.08
	MRL	28	-1.25	-0.76	29.96	8.87		-0.17
	RL	24	-0.54	-0.31	32.13	8.72		-0.07
	COHORT	104	-		30.95	8.64		-
CONCEPTS	MM	25	0.64	0.86	14.44	4.67	3.27	0.20
	MRL	28	-1.11	-1.53	12.93	4.86		-0.34
	RL	24	0.21	0.28	15.33	3.59		0.06
	COHORT	104	-		13.86	3.92		-
APPLICATIONS	MM	25	0.30	0.32	13.04	5.47	4.14	0.07
	MRL	28	-0.84	-0.91	12.04	6.32		-0.20
	RL	24	-1.06	-1.09	13.21	5.86		-0.26
	COHORT	104	-		12.49	5.28		-
MATH TOTAL	MM	25	1.56	0.57	59.48	17.77	12.10	0.13
	MRL	28	-3.20	-1.19	54.93	18.29		-0.26
	RL	24	-1.39	-0.49	60.67	14.73		-0.11
	COHORT	104	-		57.30	15.71		-

Table 4-72

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COHORTS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS) Subject = READING

Treatment effects and posttest means by treatment group,
Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 156df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	25	-2.46	-1.27	40.40	6.93	8.31	-0.30
	MRL	28	0.72	0.38	42.93	6.20		0.09
	RL	28	2.17	1.13	45.61	6.03		0.26
	COHORT	90	-		41.34	7.28		-
PART B	MM	25	0.25	0.12	34.76	7.32	8.48	0.03
	MRL	28	0.51	0.26	37.50	6.29		0.06
	RL	28	2.68	1.38	39.96	5.21		0.32
	COHORT	90	-		34.48	10.09		-
READING TOTAL	MM	25	-2.22	-0.62	75.16	13.37	15.26	-0.15
	MRL	28	1.22	0.35	80.43	11.79		0.08
	RL	28	4.85	1.38	85.57	10.79		0.32
	COHORT	90	-		75.82	16.18		-

CTBS	Treatment Group	N	Treatment Effect	(t) 164df	Posttest $\overline{X}$	Posttest SD	Residual SD	Standardized T.E.
VOCABULARY	MM	26	-2.05	-1.45	21.69	8.02	6.19	-0.33
	MRL	29	0.36	0.26	23.79	7.64		0.06
	RL	26	0.19	0.13	26.39	7.61		0.03
	COHORT	98	-		23.16	8.30		-
COMPREHENSION	MM	26	0.74	0.49	25.62	9.99	6.61	0.11
	MRL	29	-1.60	-1.08	23.17	9.41		-0.24
	RL	26	-0.33	-0.21	27.19	8.94		-0.05
	COHORT	98	-		23.66	8.48		-
READING TOTAL	MM	26	-1.32	-0.50	47.31	17.19	11.55	-0.11
	MRL	29	-1.24	-0.48	46.96	16.12		-0.11
	RL	26	-0.15	-0.05	53.78	15.70		-0.01
	COHORT	98	-		46.83	15.88		-

Table 4-73

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COHORTS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS)   Subject = LANGUAGE

Treatment effects and posttest means by treatment group, Schools = 2-4.

CST	Treatment Group	N	Treatment Effect	(t) 156df	Posttest		Residual SD	Standardized T.E.
					$\overline{X}$	SD		
PART A	MM	25	-0.83	-0.62	36.72	10.83	5.71	-0.14
	MRL	28	2.04	1.55	40.25	9.09		0.36
	RL	28	3.59	2.73	42.89	7.74		0.63
	COHORT	90	-		39.06	10.03		-
PART B	MM	25	0.29	0.17	30.96	10.29	7.30	0.04
	MRL	28	3.58	2.14	31.54	11.92		0.49
	RL	28	4.16	2.48	36.11	10.14		0.57
	COHORT	90	-		30.14	11.18		-
LANGUAGE TOTAL	MM	25	-0.54	-0.20	67.68	19.90	11.75	-0.05
	MRL	28	5.61	2.08	71.79	19.96		0.48
	RL	28	7.75	2.87	79.00	15.98		0.66
	COHORT	90	-		69.47	19.83		-

CTBS	Treatment Group	N	Treatment Effect	(t) 164df	Posttest		Residual SD	Standardized T.E.
					$\overline{X}$	SD		
SPELLING	MM	26	-0.66	-0.49	34.04	9.34	5.91	-0.11
	MRL	29	0.71	0.54	35.41	8.44		0.12
	RL	26	0.66	0.47	38.31	7.97		0.11
	COHORT	98	-		35.05	15.88		-
MECHANICS	MM	26	-0.39	-0.54	11.39	4.12	3.20	-0.12
	MRL	29	0.66	0.92	11.97	4.35		0.21
	RL	26	1.01	1.32	13.50	3.03		0.32
	COHORT	98	-		11.58	3.87		-
EXPRESSION	MM	26	-0.57	-0.53	19.34	7.19	4.69	-0.12
	MRL	29	-0.49	-0.47	19.14	7.70		-0.10
	RL	26	0.58	0.52	22.31	6.16		0.12
	COHORT	98	-		19.16	6.08		-
LANGUAGE TOTAL	MM	26	-1.62	-0.66	64.77	17.82	10.77	-0.15
	MRL	29	0.88	0.37	66.52	18.65		0.08
	RL	26	2.24	0.88	74.12	15.40		0.21
	COHORT	98	-		65.80	14.98		-

Grades 4-6: CAI vs comparisons. Table 4-74 presents the mathematics results when CAI students are compared with students in Schools 5 and 6 without CAI. There are no statistically significant treatment effects, although one can see in the CST data the expected pattern of effects within the three CAI groups.

Table 4-75 presents the reading results. Only the negative treatment effect for the MM group on part A of the CST is statistically significant. For the CTBS data, treatment effects for the RL and MRL groups in vocabulary are strongly positive although not significant.

Table 4-76 presents the language results. For the CST data, treatment effects for the RL group are statistically significant. None of the treatment effects for subtests of the CTBS is significant.

Table 4-74

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COMPARISONS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS)   Subject = MATHEMATICS

Treatment effects and posttest means by treatment group,
Schools = 2-4 vs. 5-6.

CST	Treatment Group	N	Treatment Effect	(t) 163df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
PART A	MM	30	3.09	1.77	38.50	9.60	7.74	0.39
	MRL	32	2.38	1.29	36.41	9.93		0.31
	RL	25	-1.10	-0.58	35.40	8.42		-0.14
	COMPARISON	85	-		35.45	10.40		-
PART B	MM	30	0.94	0.56	27.87	10.02	7.43	0.13
	MRL	32	1.19	0.67	26.69	9.43		0.16
	RL	25	-1.74	-0.95	26.20	6.20		-0.23
	COMPARISON	85	-		26.85	10.26		-
MATH TOTAL	MM	30	4.03	1.24	66.37	19.10	14.40	0.28
	MRL	32	3.57	1.04	63.09	18.73		0.25
	RL	25	-2.85	-0.80	61.60	13.79		-0.20
	COMPARISON	85	-		62.29	20.18		-

CTBS	Treatment Group	N	Treatment Effect	(t) 162df	Posttest $\bar{X}$	Posttest SD	Residual SD	Standardized T.E.
COMPUTATION	MM	28	-1.42	-0.79	32.46	9.54	7.67	-0.19
	MRL	33	-2.16	-1.21	30.76	8.42		-0.28
	RL	26	-2.46	-1.32	32.27	8.40		-0.32
	COMPARISON	84	-		34.56	9.61		-
CONCEPTS	MM	28	0.30	0.39	14.89	5.03	3.38	0.09
	MRL	33	-0.84	-1.07	13.18	4.70		-0.25
	RL	26	0.47	0.58	15.50	3.52		0.14
	COMPARISON	84	-		14.99	5.10		-
APPLICATIONS	MM	28	0.19	0.17	13.43	5.89	4.93	0.04
	MRL	33	0.28	0.24	12.79	6.33		0.06
	RL	26	-0.53	-0.44	13.27	5.80		-0.11
	COMPARISON	84	-		13.21	7.01		-
MATH TOTAL	MM	28	-0.92	-0.30	60.79	19.15	13.07	-0.07
	MRL	33	-2.73	-0.89	56.73	17.65		-0.21
	RL	26	-2.51	-0.79	61.04	14.29		-0.19
	COMPARISON	84	-		62.76	19.40		-

Table 4-75

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COMPARISONS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS)   Subject = READING

Treatment effects and posttest means by treatment group,
Schools = 2-4 vs. 5-6.

CST	Treatment Group	N	Treatment Effect	(t) 170df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
PART A	MM	28	-4.39	-2.60	37.07	10.74	7.22	-0.61
	MRL	33	-0.69	-0.42	40.42	8.88		-0.10
	RL	30	0.85	0.50	43.17	7.55		0.12
	COMPARISON	92	-		40.77	8.10		-
PART B	MM	28	-0.18	-0.10	31.61	10.75	7.95	-0.02
	MRL	33	0.64	0.35	31.82	11.69		0.08
	RL	30	2.79	1.50	36.57	9.79		0.35
	COMPARISON	92	-		32.05	10.99		-
READING TOTAL	MM	28	-4.57	-1.39	68.68	20.76	13.99	-0.33
	MRL	33	-0.05	-0.02	72.24	19.68		0.00
	RL	30	3.65	1.11	79.73	15.68		0.26
	COMPARISON	92	-		72.83	18.30		-

CTBS	Treatment Group	N	Treatment Effect	(t) 171df	Posttest		Residual SD	Standardized T.E.
					$\bar{X}$	SD		
VOCABULARY	MM	29	-0.06	-0.05	22.17	8.89	5.97	-0.01
	MRL	34	2.32	1.70	23.62	7.99		0.39
	RL	28	2.61	1.83	26.89	7.70		0.44
	COMPARISON	93	-		22.71	8.86		-
COMPREHENSION	MM	29	0.96	0.60	26.31	10.64	6.86	0.14
	MRL	34	-0.81	-0.52	23.74	9.95		-0.12
	RL	28	0.16	0.10	27.50	8.81		0.02
	COMPARISON	93	-		24.82	10.25		-
READING TOTAL	MM	29	0.90	0.33	48.48	18.83	11.82	0.08
	MRL	34	1.51	0.56	47.35	17.09		0.13
	RL	28	2.77	0.98	54.39	15.69		0.23
	COMPARISON	93	-		47.53	18.51		-

Table 4-76

Longitudinal Analysis for GRADE 4 to GRADE 6: CAI vs. COMPARISONS

PERIOD = YEAR 1 TO YEAR 3

Posttest= CST & CTBS (from ITBS) Subject = LANGUAGE

Treatment effects and posttest means by treatment group, Schools = 2-4 vs. 5-6.

CST	Treatment Group	N	Treatment Effect	(t) 170df	Posttest		Residual SD	Standardized T.E.
					$\overline{X}$	SD		
PART A	MM	28	-0.33	-0.27	41.04	7.29	5.11	-0.06
	MRL	33	2.26	1.91	43.00	6.18		0.44
	RL	30	3.60	3.01	46.00	6.07		0.70
	COMPARISON	92	-		41.40	6.76		-
PART B	MM	28	-1.57	-1.39	35.79	7.77	4.83	-0.32
	MRL	33	1.14	1.02	37.64	6.39		0.24
	RL	30	2.65	2.34	40.33	5.48		0.55
	COMPARISON	92	-		36.83	6.15		-
LANGUAGE TOTAL	MM	28	-1.89	-0.90	76.82	14.26	8.99	-0.21
	MRL	33	3.40	1.64	80.64	11.82		0.38
	RL	30	6.25	2.97	86.33	11.11		0.70
	COMPARISON	92	-		78.23	12.15		-

CTBS	Treatment Group	N	Treatment Effect	(t) 171df	Posttest		Residual SD	Standardized T.E.
					$\overline{X}$	SD		
SPELLING	MM	29	-1.03	-0.65	34.79	9.05	6.82	-0.15
	MRL	34	-0.27	-0.17	35.71	8.49		-0.04
	RL	28	0.55	0.34	38.21	8.14		0.08
	COMPARISON	93	-		36.24	9.11		-
MECHANICS	MM	29	-0.69	-0.93	11.69	4.53	3.22	-0.21
	MRL	34	0.51	0.69	12.21	4.44		0.16
	RL	28	0.86	1.12	13.71	3.09		0.27
	COMPARISON	93	-		12.77	4.02		-
EXPRESSION	MM	29	-0.56	-0.49	19.93	7.91	4.92	-0.11
	MRL	34	-0.35	-0.31	19.44	7.84		-0.07
	RL	28	0.60	0.51	22.50	6.07		0.12
	COMPARISON	93	-		19.96	6.61		-
LANGUAGE TOTAL	MM	29	-2.29	-0.80	66.41	18.90	12.36	-0.18
	MRL	34	-0.10	-0.04	67.35	19.09		0.01
	RL	28	2.01	0.68	74.43	15.53		0.16
	COMPARISON	93	-		68.97	17.63		-

Discussion for Grades 4-6

Discussion of the data from the fourth- through sixth-grade longitudinal study will focus on the three curriculum areas: mathematics, reading, and language arts.

Mathematics. Table 4-77 presents an overview of the CAI treatment effects in standard-deviation units for mathematics. One-year studies are presented in the top row followed by the six longitudinal studies which have been reviewed. Wherever the treatment effect is followed by an asterisk, the effect is statistically significant.

The CAI treatment effects are shown consistently by the curriculum-specific tests. Except in relation to the comparison schools, the MM group consistently performed anywhere from two-thirds of a standard deviation to more than a standard deviation above the level of the RL group. Clearly, the drill-and-practice mathematics CAI curriculum is capable of increasing students' skills in mathematical computation.

The data from the CTBS are less striking. The within-CAI analyses show the MM group consistently superior in computation to the RL group with which it is being compared. In most cases, the performance of the MM group in computation is close to two-thirds of a standard deviation above that of the RL group and is statistically significant. The MM group also tends to show improved performance in mathematics concepts and applications over time, especially in the first of the longitudinal studies.

The fourth- through sixth-grade study is not consistent with regard to the relationship between the amount of mathematics CAI and test performance. In the one-year studies at grades 5 and 6, the CST data and CTBS computation data would seem to indicate that students with two sessions of mathematics

Table 4-77

Treatment Effects Given in Standard Deviations for Mathematics Scores for the Longitudinal CAI Cohort, Grades 4-6.

	Grade 4		Grade 5		Grade 6	
One-Year Studies	MM & MRL vs. RL		MM & MRL vs. RL		MM & MRL vs. RL	
	MM	MRL	MM	MRL	MM	MRL
CST	.90*	.33	.78*	.38*	.83*	.48*
COMPUTATION	-.01	-.27	.37*	.19	.33	.16
CONCEPTS	-.33	-.25	-.02	-.27	.05	-.09
APPLICATIONS	-.23	-.31	-.09	.04	.26	.21
Longitudinal		MM & MRL vs. RL				
CST					.97*	.75*
COMPUTATION					.64*	.75*
CONCEPTS					.28	.16
APPLICATIONS					.58	.65*
		MM & MRL vs. RL				
			MM	MRL		
CST			1.42*	.84*		
COMPUTATION			.76	.60		
CONCEPTS			.25	-.06		
APPLICATIONS			.12	.28		
	MM & MRL vs. RL					
CST			1.10*	.39*		
COMPUTATION			.63*	.25		
CONCEPTS			.21	-.15		
APPLICATIONS						
			MM & MRL vs. RL			
CST					.65*	.48
COMPUTATION					.28	.23
CONCEPTS					-.03	-.22
APPLICATIONS					.20	.36
	MM, MRL & RL vs. Cohort Controls					
			MM		MRL	RL
CST			1.11*		.83*	.57*
COMPUTATION			.08		-.17	-.07
CONCEPTS			.20		-.34	.06
APPLICATIONS			.07		-.20	-.26
	MM, MRL & RL vs. Comparison Schools					
			MM		MRL	RL
CST			.28		.25	-.20
COMPUTATION			-.19		-.28	-.32
CONCEPTS			.09		-.25	.14
APPLICATIONS			.04		.06	-.11

$^*p < .05$

CAI daily have treatment effects about twice the size of those achieved by students with only one session. In the four longitudinal studies involving only CAI students, the MRL group is better than the MM group, roughly equivalent, and markedly or slightly inferior. The inconsistency of the relationship reflects in part the inconsistencies in the grade 4 data. There are several problems. The problem of randomization has already been discussed. Another difficulty with regard to mathematics is the character of the ITBS mathematics pretest. It is as much a test of reading as of mathematics for many of the students in the study. There is no strictly computational component. There are surprisingly high mathematics ITBS scores for some Hispanic students, and the possibility that questions were read in Spanish to bilingual students in some classes cannot be overlooked. The overall ITBS scores in grade 4 were especially high in year 1. Added to those complications were differential attrition rates over time, with brighter students leaving the MM and MRL groups and slower students leaving the RL group. Given the inconsistencies, some average of the treatment effects for the MRL group would give the best estimate of the effect of the MRL treatment. That would place the MRL group between one-third and one-half of a standard deviation above the RL group but still below the MM group.

The cohort control and comparison school regressions are also confounded because of the problems with the grade 4 data. Patterns of superiority of the MM group over the RL group on mathematics achievement remain, but except for the CST data for CAI students vs. the cohort controls, none of the treatment effects is significant. We will examine the cohort control data more closely in a later discussion.

Reading. Table 4-78 presents an overview of the CAI treatment effects in terms of standard deviations for the grades 4-6 longitudinal study of reading. For the RL group, only one of the one-year studies and one of the longitudinal studies report statistically significant treatment effects on the CSTs. For the MRL group there is only one significant treatment effect for the CST in the grade 4 one-year study. In all cases the RL group's performance is superior to the MM group's on the reading CST, but there is not the striking effect found, for example. on the mathematics CST.

There is some indication at the sixth-grade level that RL and, more specifically, MRL students performed better on the CTBS vocabulary subtest than did MM students. Whether one uses as pretests the CTBS from grade 4, the ITBS from grade 5 or the ITBS from grade 6, the CTBS data for grade 6 show significant treatment effects for the RL group. It is strange, however, that the effects do not show up at grade 5 when the same posttest was administered.

The CTBS comprehension subtest shows no significant treatment effects. More often than not the within-CAI treatment effects for comprehension are negative.

Overall, no strong, sure, longitudinal patterns emerge from the reading results of the fourth- through sixth-grade longitudinal study.

Table 4-78

Treatment Effects Given in Standard Deviations for Reading Scores for the Longitudinal CAI Cohort, Grades 4-6.

	Grade 4		Grade 5		Grade 6	
One-Year Studies	RL & MRL vs. MM		RL & MRL vs. MM		RL & MRL vs. MM	
	RL	MRL	RL	MRL	RL	MRL
CST	.93*	.36*	.22	-.10	.44	.18
VOCABULARY	.28	.04	-.03	.03	.45*	.51*
COMPREHENSION	.23	-.04	-.09	-.25	.03	-.06
Longitudinal			RL & MRL vs. MM			
CST					0.42.	0.40
VOCABULARY					0.58	0.72*
COMPREHENSION					-0.24	-0.20
			RL & MRL vs. MM			
CST			.23	-.13		
VOCABULARY			.02	.03		
COMPREHENSION			-.04	-.16		
	RL & MRL vs. MM					
CST			.50*	-.20		
VOCABULARY			.08	.08		
COMPREHENSION			-.07	-.29		
			RL & MRL vs. MM			
CST					.32	.10
VOCABULARY					.28	.48
COMPREHENSION					-.24	-.09
	RL, MRL & MM vs. Cohort Controls					
			RL		MRL	MM
CST			.32		.08	-.15
VOCABULARY			.03		.06	-.33
COMPREHENSION			-.05		-.24	.11
	RL, MRL & MM vs. Comparison Schools					
			RL		MRL	MM
CST			.26		.00	-.33
VOCABULARY			.44		.39	-.01
COMPREHENSION			.02		-.12	-.14

*p < .05

Language. Table 4-79 presents an overview of the treatment effects in language for the fourth- through sixth-grade longitudinal cohort. In contrast to the CST results in reading, the language CST results are positive, consistent, and, for the RL group, all statistically significant. The CAI language arts curriculum is clearly teaching something demonstrable and is increasing students' skills in specific aspects of language. In all cases, the MRL group has treatment effects on the CST above those of the MM group and below those of the RL group, as might be expected.

The CTBS data are, again, less striking than the CST data. If we concentrate on the RL group's performance, we see several positive and one statistically significant treatment effect in spelling. For mechanics, all of the treatment effects are positive, although none is statistically significant. There are mixed results for language expression. When contrasted to the cohort controls or to comparison school students, the RL students performed better on all language tests but especially on language mechanics.

Overall, results on language variables are more positive than the results for reading and less positive than the results for mathematics. Since the RL group had only 10 minutes per day in the language CAI treatment compared to 20 minutes in mathematics for the MM group, it should not be surprising that treatment effects are weaker.

Table 4-79

Treatment Effects Given in Standard Deviations for Language Scores for the Longitudinal CAI Cohort, Grades 4-6.

	Grade 4		Grade 5		Grade 6	
One-Year Studies	RL & MRL vs. MM		RL & MRL vs. MM		RL & MRL vs. MM	
	RL	MRL	RL	MRL	RL	MRL
CST	1.09*	.42*	.74*	.16	.53*	.25
SPELLING	.34	.08	.22	-.16	-.03	-.13*
MECHANICS	.21	-.01	.16	.16	.21	.07
EXPRESSION	.21	-.07	-.38	-.25	.20	.17
Longitudinal		RL & MRL vs. MM				
CST					.76*	.59*
SPELLING					.22	.38
MECHANICS					.09	.22
EXPRESSION					.22	.14
		RL & MRL vs. MM				
CST			.59*	.18		
SPELLING			.26	-.06		
MECHANICS			.10	.31		
EXPRESSION			-.40	-.29		
	RL & MRL vs. MM					
CST			.74*	.14		
SPELLING			.46*	-.26		
MECHANICS			.34	.29		
EXPRESSION			-.12	-.40		
			RL & MRL vs. MM		RL	MRL
CST					.57*	.20
SPELLING					-.06	.12
MECHANICS					.18	.27
EXPRESSION					.04	.15
	RL, MRL & MM vs. Cohort Controls					
			RL		MRL	MM
CST			.66*		.48*	-.05
SPELLING			.11		.12	-.11
MECHANICS			.32		.21	-.12
EXPRESSION			.12		-.10	-.12
	RL, MRL & MM vs. Comparison Schools					
			RL		MRL	MM
CST			.70*		.38	-.21
SPELLING			.08		-.04	-.15
MECHANICS			.27		.16	-.21
EXPRESSION			.12		-.07	-.11

*p < .05

Chapter V

TREATMENT EFFECTS: THE BIG PICTURE

In this chapter the findings of the one-year studies reported in Chapter III and the longitudinal studies reported in Chapter IV will be consolidated. The one-year studies will be examined first, followed by the longitudinal studies. Finally, CAI students will be examined in contrast with cohort controls and comparison students.

One-Year Studies

In this section of the report treatment effects will be discussed--not in terms of numbers of items as in earlier tables (4-2 to 4-76)--but in terms of standard deviations as in Tables 4-77 to 4-79. Table 4-80 presents an overview of all the CAI treatment effects in the 12 one-year studies arranged so that overall patterns may be seen. Entries can be interpreted to show how far above (+) or below (-) the adjusted mean of the control group lies the adjusted mean for the treatment group. The first entry, 1.16*, indicates that the M group, receiving one session of mathematics CAI daily, performed 1.16 standard deviations above the control group on the mathematics curriculum-specific test (CST). The asterisk indicates that the treatment effect was statistically significant. In all cases the standard deviation used is the residual standard deviation which appeared in the last column of Tables 4-2 to 4-76. Our discussion of the one-year studies will be presented in three sections, one for each of the three curriculums: mathematics, reading and language.

Mathematics

The mathematics CSTs were developed to test whether the CAI curriculum

Table 4-80

Treatment Effects in Standard Deviations: All One Year Studies

			MATHEMATICS						READING					LANGUAGE					
Treatment Conditions	Grade	Year	Group	Math. CST	Computation	Concepts	Application	Math. Total	Group	Read. CST	Voca.	Comp.	Read. Total	Group	Lang. CST	Spelling	Mechanics	Expression	Lang. Total
M vs. O	1	2	M	1.16*	.12	.37*	-	.25											
MM vs. M	2	1	MM	.08	.35*	.33*	-												
M vs. O	2	3	M	.79*	.51*	.31*	-	.51*											
MM vs. ML	3	2	MM	.67*	.38*	-.03	.04	.23	ML	-.15	-.16	-.29	-.28	ML	.46*	-.12	.10	.01	-.05
M vs. L	3	4	M	.82*	.30	-.20	.02	.13	L	.15	.34*	.27	.34*	L	.41*	.51*	.31	.12	.47*
MM/MRL/RL	4	1	MM	.90*	-.01	-.33	-.23	-.18	RL	.47*	.28	.23	.28	RL	1.09*	.34	.21	.21	.35
			MRL	.33	-.27	-.25	-.31	-.35*	MRL	.09*	.04	-.04	.00	MRL	.42*	.08	-.01	-.07	.02
MM vs. RL	4	3	MM	.63*	.28*	.06	.10	.22	RL	.34*	.25	.26*	.29*	RL	.65*	.03	.41*	.33*	.28*
M/R/L/C	4	4	M	.69*	.43	.07	.04	.27	R	.50*	.26	.18	.26	R	.50*	.25	.33*	.25	.35*
									L	.25	.36	.21	.32	L	.80*	.48*	.44*	.20	.50*
									C	.39	.21	.30	.30	C	-	.17	.33	.45*	.39
MM/MRL/RL	5	2	MM	.78*	.37*	-.02	-.09		RL	.22	-.03	-.09	-.08	RL	.74*	.22	.16	-.38	.00
			MRL	.38*	.19	-.27	.04		MRL	-.10	.03	-.25	-.14	MRL	.16	-.16	.16	-.25	-.16
MM vs. RL	5	4	MM	.76*	.52*	-.10	-.16	.25	RL	.20	.23	.31	.33	RL	.56*	-.09	.21	.33	.15
MM/RR/LL/RL	6	1	MM	1.44*	.16	-.09	-.09	.04	RR	.57*	.26	.45*	.43*	RR	.12	-.08	.29	.13	.09
									RL	.29	.28	.51*	.47*	RL	.88*	.11	.18	.12	.17
									LL	-.13	-.16	.09	-.03	LL	.94*	-.10	.08	-.09	-.08
MM/MRL/RL	6	3	MM	.83*	.33	.05	.26	.30	RL	.44	.45*	.03	.26	RL	.53*	-.03	.21	.20	.12
			MRL	.48*	.16	-.09	.21	.15	MRL	.18	.51*	-.06	.23	MRL	.25	-.13	.07	.17	.01

*$p < .05$

was, in fact, doing what it intended to do. Students who received mathematics CAI were expected to do better on a test of that CAI curriculum than students who had not. The treatment effects on the mathematics CST are consistently high, positive and statistically significant. In looking for patterns associated with the amount of CAI, the grade level, the control group, and other complicating factors, two patterns emerge. Students who received two sessions daily of mathematics CAI (MM) reported treatment effects about twice the size of students who had received only one session (MRL) in grades 4, 5 and 6. That pattern is repeated often in Table 4-80. A second pattern involves the results of the first exposure to a CAI curriculum vs the results of later exposures. In those cases in which mathematics CAI students are compared with non-math students--grade 1, grade 4 in years 1 and 4, and grade 6 in year 1--treatment effects are quite high, averaging 1.05 standard deviations. Treatment effects after the first exposure are lower, averaging .75. This pattern also will be repeated for CSTs in reading and language.

For the CTBS computation subtest, the results for mathematics CAI students parallel the CST results, although the treatment effects are not nearly as high. Omitting the year 1 data, when the CTBS test was administered only two months after CAI treatments were initiated, and also ignoring for the moment students exposed to the MRL condition, adjusted means for students receiving mathematics CAI average one-third of a standard deviation higher than those for students without mathematics CAI. In grades 5 and 6, MRL students have treatment effects only half the size of MM students.

For the CTBS concepts and applications subtest(s), the results are mixed. In grades 1 and 2 when the subtest is read to students, the treatment effects for math CAI students are positive and statistically significant. In grades 3-6 when math CAI students are compared to CAI students with exposure to reading and/or language and when students must read their own mathematics problems, the results are not consistent.

Reading

The reading CAI curriculum was not used until grade 4. In the four studies involving the first exposure of CAI students to the reading curriculum--grade 4 in years 1, 3 and 4 and grade 6 in year 1--treatment effects on the reading CST for students receiving the maximum exposure average .59 and are statistically significant. In the later studies in grades 5 and 6, treatment effects on the reading CST average .29 and are not significant.

On the CTBS vocabulary and comprehension subtests, most groups receiving reading CAI show small positive treatment effects averaging about one-quarter of a standard deviation. Few of the effects are statistically significant.

Language Arts

The language CST data resemble the mathematics CST data more than they do the reading CST data in that there are statistically significant treatment effects in every study. Treatment effects for first-year exposure average .74, or .94 without grade 3 students. Later studies show treatment effects averaging .62. The content of the language CAI curriculum demonstrates more capability of differentiating between users and non-users than does the content of the reading curriculum.

All of the statistically significant treatment effects on the CTBS language subtests occur in grades 3 and 4. On the spelling subtest, treatment effects are variable: mainly positive and twice significant in grades 3 and 4, slight and negative in grades 5 and 6. Treatment effects in language mechanics average close to one-quarter of a standard deviation, and although the effects are larger and sometimes significant in the earlier grades, small positive effects are shown in grades 5 and 6. There are also small positive effects for language expression, but it is interesting that the largest significant treatment effect was obtained by the group receiving the newer reading-for-comprehension CAI curriculum in grade 4, year 4.

Longitudinal Studies

The longitudinal studies will also be reviewed with treatment effects defined in terms of standard deviations. Emphasis in this section is placed on the CAI curriculums and what they accomplished in one-year and longitudinal studies.

Mathematics

The mathematics curriculum had the length and breadth to handle all of the students in the CAI study over four-year duration. Only two students topped out: both were girls who had been in the program for four years, receiving 20 minutes of mathematics CAI daily before they topped out. All students were able to access the mathematics curriculum. Kindergarten students, who were not in the study, visited the CAI lab in one of the schools on a regular basis.

Students at all grade levels benefited from the CAI curriculum and there were indications that long-term students showed continuing gains over time. See Table 4-81. There were 12 one-year studies in which students receiving the CAI mathematics curriculum were compared with students receiving no CAI (two studies), less math CAI (two studies), or other CAI treatments such as reading or language (eight studies). The average treatment effect for the 12 one-year studies is .80 on the curriculum specific test of mathematics, indicating that students receiving math CAI are four-fifths of a standard deviation higher in math performance on the CST. For the six two-year studies the average treatment effect is .91, and for the three three-year studies it is 1.23. Over time, the mathematics CAI groups increased their mean distance from the non-math CAI group on the test of the CAI curriculum.

On the standardized test--the CTBS--the 12 one-year studies showed an average treatment effect of .31 of a standard deviation on math computation. That figure rose to an average of .36 when first year studies were omitted because testing occurred only two months after the CAI labs opened. For the six two-year studies the average treatment effect is .56 and for the two three-year studies it is .72. Over time, the mathematics CAI groups increased their distance from the non-math CAI groups on the CTBS computation subtest.

On the CTBS concepts and applications subtests, the results are less clear. Test items contain words to be read as well as mathematical concepts and applications. In grades 1 and 2, concepts and applications problems were read to the students, and under those circumstances CAI

Table 4-81

Summary Table for One-Year and Longitudinal Treatment Effects: Mathematics

	GRADE 1			GRADE 2			GRADE 3			GRADE 4			GRADE 5			GRADE 6		
	1 Year	2 Year	3 Year	1 Year	2 Year	3 Year	1 Year	2 Year	3 Year	1 Year	2 Year	3 Year	1 Year	2 Year	3 Year	1 Year	2 Year	3 Year
YEAR 1																		
CST				.08						.90*						1.44*		
COMPUTATION				.35*						-.01						.16		
CONCEPTS				.33*						-.33						-.09		
APPLICATION										-.23						-.09		
YEAR 2																		
CST	1.16*						.67*						.78*	1.10*				
COMPUTATION	.12						.38						.37*	.63*				
CONCEPTS	.37*						-.03						-.02	.21				
APPLICATION							.04						-.09	.07				
YEAR 3																		
CST				.79*	.66*					.63*	.99*					.83*	.65*	.97*
COMPUTATION				.51*	.67*					.28*	.59*					.33	.28	.64*
CONCEPTS				.31*	.50					.06	.21					.05	-.03	.28
APPLICATION										.10	.36					.26	.20	.58
YEAR 4																		
CST							.82*	.91*	1.54*	.69*			.76*	1.18*	1.17*			
COMPUTATION							.30	.61	-	.43			.52*	.57*	.79*			
CONCEPTS							-.20	.44	-	.07			-.10	-.21	-.10			
APPLICATION							.02	.19	-	.04			-.16	-.20	-.05			

*p <.05

treatment effects in the one-year studies average one-third of a standard deviation and are statistically significant. The one two-year study showed a treatment effect of .50. In grades 3-6 students read their own test questions, and since math CAI students were being compared with students receiving reading and/or language CAI, the results may have been confounded. No statistically significant treatment effects for either concepts or applications occur in grades 3-6. Table 4-82 and Figure 4-2 summarize the final estimates of treatment effects in mathematics. Overall, the mathematics strands curriculum performed very well. It adapted to students of all ability levels and provided effective drill and practice in mathematics computation. Its effectiveness was demonstrated both in one-year studies and over two- and three-year periods.

Table 4-82

Summary of the 1-Year, 2-Year, and 3-Year
Studies of Mathematics CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Math CST	12	6	3	.80**	.91**	1.23**	79	82	89
CTBS Computation	9	6	2	.36**	.56**	.72**	64	71	76
CTBS Concepts	7	5	2	-.02	.12	.09	49	55	54
CTBS Applications	7	5	2	.03	.12	.26	51	55	60
CTBS Concepts & Applications[1]	2	1	0	.34**	.50	-	63	69	-

** $p < .01$.

[1] In grades 1 and 2 Concepts and Applications is a single subtest.

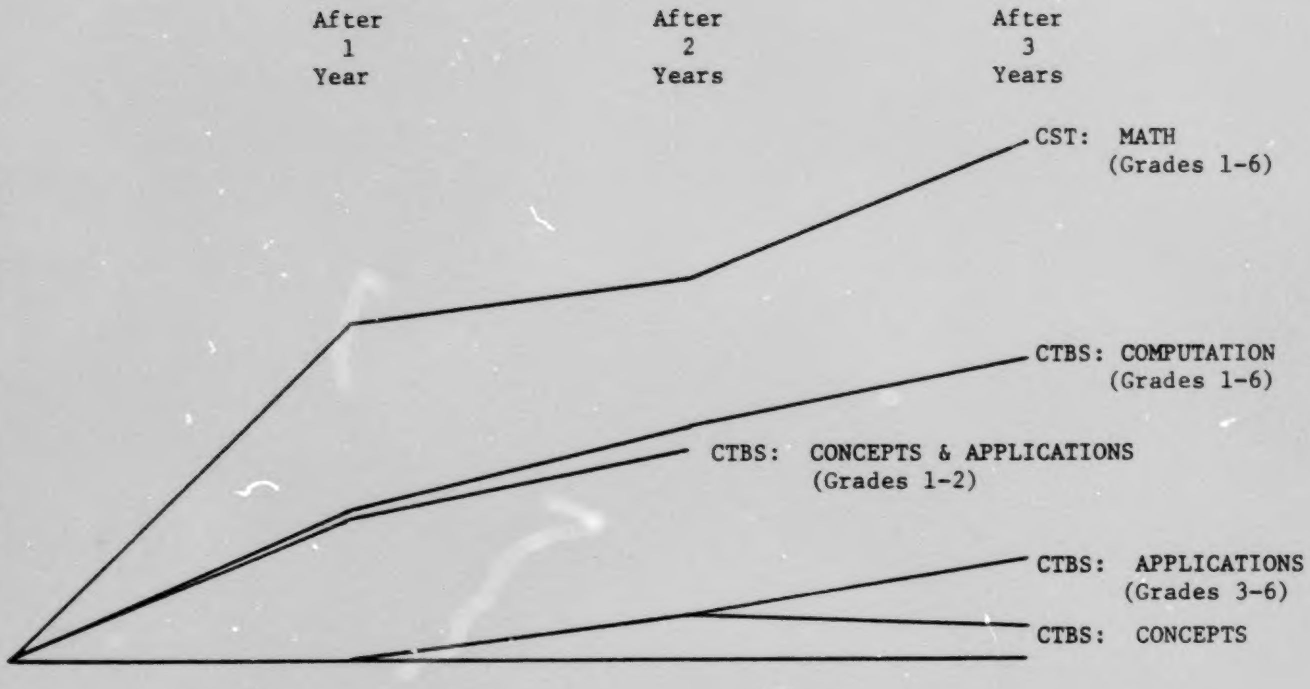


Figure 4-2 Mathematics Treatment Effects Over 3 Years.

Reading and Language

The CAI reading curriculum used in this study was developed for students in grades 3-6, with an addition of basic sentences which purported to reach students at grade level 2.5. For the students in our study, those estimates were misleading. At grade 4 many students assigned to the reading/language (RL) CAI treatment were transferred to the MM group after six to eight weeks. CAI coordinators kept students in the assigned curriculums for four to six weeks after the rapid motion phase of the CAI curriculum had placed students at their own ability levels. When a student had made absolutely no progress after four to six weeks and the curriculum was deemed unsuitable by the CAI coordinator, the student's curriculum was changed. In one of the Title I schools the most frequent reason for the change was that the student was a non-reader. In the other Title I school the most frequent reason was that the student was Spanish-speaking. It is clearly a drawback when accessibility to a reading drill-and-practice CAI curriculum is dependent on the ability to read relatively well. On the other hand, at grade 6 the reading CAI curriculum sometimes proved to be too easy. A few students topped out of the reading curriculum during the rapid motion phase. A few students assigned to two sessions of reading daily topped out within a few months, although generally speaking progress was very slow in the reading curriculum.

The language curriculum was designed for students in grades 3-6, and because its vocabulary was simpler than that in the reading curriculum it caused fewer problems of accessibility in the early grades. On the other hand, it caused more frequent problems in grade 6 with students topping out. Relatively large numbers of students who were assigned to two sessions of language CAI daily in the latter half of sixth grade topped out of the curriculum in the rapid motion phase, and others topped out within a few months. Progress in the language curriculum was more rapid than progress in reading. For students interested in achieving, the more rapid progress was pleasing.

The length and breadth of the reading and language CAI curriculums did not purport to be as great as the mathematics CAI curriculum. Perhaps this is less of a problem for the use of the curriculums in elementary schools than it was for the evaluation of the curriculums in this study. Schools after all would not generally assign students randomly to a CAI curriculum. However, there are limitations to the use of these specific reading and language curriculums even though they were the broadest available when the study started. Perhaps with newer technology a reading/language CAI curriculum can be built which will have the broad applicability that the mathematics curriculum enjoys.

Table 4-83 summarizes CAI treatment effects in the one-, two- and three-year studies of reading and language. The reading results will be discussed first. Since the CAI reading curriculum was used only in grades 4-6, only seven one-year studies are applicable. Two of those studies occurred in the first year when CAI labs did not open until late January or February, yet those treatment effects are among the highest found.

For the six one-year studies in which students assigned to both reading and language CAI were compared to MM students, the mean treatment effects for the CST and the vocabulary and comprehension subtests of the CTBS are .33, .24 and .21. For students assigned only to reading CAI (grade 6, year 1 and grade 4, year 4) those figures are .53, .26 and .31. The means of the 8 treatment groups receiving reading CAI are .38 on the CST, .25 on CTBS Vocabulary and .23 on CTBS Comprehension. For the three two-year studies dealing exclusively with fourth to sixth grade, the mean treatment effects are .52, .17 and -.01. The solitary three-year study shows treatment effects of .42, .58 and -.24. Those mean treatment effects are shown in Table 4-84 and Figure 4-3.

On the basis of the single three-year study, one might reach the tentative conclusion that over the three years the RL group improved its vocabulary skills and lost comprehension skills. The evidence is certainly not strong. Whether a consistent pattern fails to emerge because of some

Table 4-83

Summary Table for One-Year and Longitudinal Treatment Effects: Reading and Language

	GRADE 3			GRADE 4			GRADE 5			GRADE 6		
	One Year Study	Longitudinal		One Year Study	Longitudinal		One Year Study	Longitudinal		One Year Study	Longitudinal	
		Two Years	Three Years		Two Years	Three Years		Two Years	Three Years		Two Years	Three Years
YEAR 1				RL vs. MM						ONE-YEAR STUDY vs. MM		
										RR	RL	LL
READING												
CST				.47*						.57*	.29	-.13
VOCABULARY				.28						.26	.28	-.16
COMPREHENSION				.23						.45*	.51*	.09
LANGUAGE												
CST				1.09 *						.12	.88*	.94*
SPELLING				.34						-.08	.11	-.10
MECHANICS				.21						.29	.18	.08
EXPRESSION				.21						.13	.12	-.09
YEAR 2	ML vs. MM						RL vs. MM					
READING												
CST	-.15						.22	.50*				
VOCABULARY	-.16						-.03	.08				
COMPREHENSION	-.29						-.09	-.07				
LANGUAGE												
CST	.46*						.74*	.74*				
SPELLING	-.12						.22	.46*				
MECHANICS	.10						.16	.34				
EXPRESSION	.01						-.38	-.12				
YEAR 3				RL vs. MM[1]						RL vs. MM		
READING												
CST				.34*	.16					.44	.32	.42
VOCABULARY				.25	.04					.45*	.28	.58
COMPREHENSION				.26*	.02					.03	-.24	-.24
LANGUAGE												
CST				.65*	.59*					.53*	.57*	.76*
SPELLING				.03	-.22					-.03	-.06	.22
MECHANICS				.41*	.34					.21	.18	.09
EXPRESSION				.31*	.15					.20	.04	.22
YEAR 4	L vs. M			ONE-YEAR STUDY vs. M			RL vs. MM[1]					
				R	L	C						
READING												
CST	.15			.50*	.25	.39	.20	.73*	. 31			
VOCABULARY	.34*			.26	.36	.21	.23	.14	-.04			
COMPREHENSION	.27			.18	.21	.30	.31	.27	.24			
LANGUAGE												
CST	.41*			.50*	.80*	-	.56*	1.14 *	.71*			
SPELLING	.51*			.25	.48	.17	-.09	.02	.06			
MECHANICS	.31			.33	.44	.33	.21	.22	.40			
EXPRESSION	.12			.25	.20	.45	.33	.13	.24			

*p <.05

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[1] The last column of figures in these two cells are based on regressions from Grade 3, where the treatment was ML rather than RL.

Table 4-84

Summary of the 1-Year, 2-Year, and 3-Year Studies of Reading CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Reading CST	8	3	1	.38**	.52**	.42	65	70	66
CTBS Vocabulary	8	3	1	.25**	.17	.58	60	57	72
CTBS Comprehension	8	3	1	.23**	-.01	-.24	59	50	41

** $p < .01$.

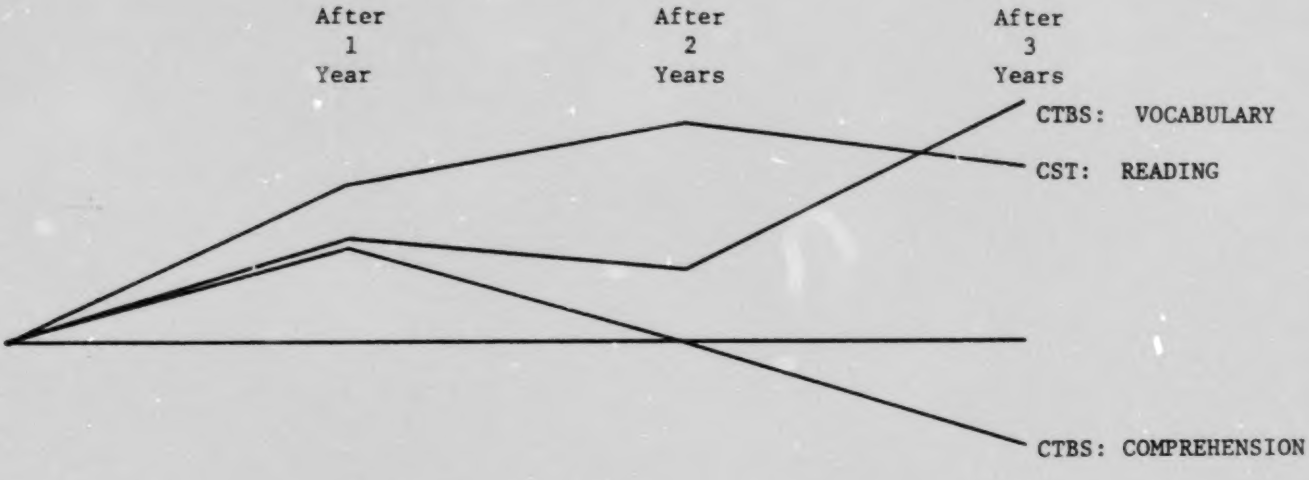

Figure 4-3 Reading Treatment Effects Over 3 Years.
(Note that 3 year effects are based on only 1 study)

quality of the curriculum, problems associated with the bottoming-out and topping-out phenomena, or some other factor, one cannot tell. One can compare the treatment effects of students receiving reading CAI with the effects associated with other verbally oriented CAI curriculums in grade 4, year 4. (See Table 4-83.) In that one-year study students assigned to language CAI or the newer reading-for-comprehension curriculum also show positive (but not significant) treatment effects on reading dependent variables. Although the reading group's treatment effects are best on the reading CST, the language group is best on vocabulary, and the reading-for-comprehension group best on comprehension.

Turning to the CAI language treatment effects, we see in Table 4-83 that there are nine one-year studies. As was the case with the reading results, the CST treatment effects in the first year of the study are the largest obtained in the four years even though students had received only four months of CAI in that school year. Averaging the treatment effects of students who received language CAI in grades 3-6, we note that all effects in the one-year studies involving the CSTs are statistically significant. That is different from the reading CST results and shows a greater differentiation between the MM and RL groups when tested on the content of the language curriculum than when tested on the content of the reading curriculum. Mean CAI treatment effects for one-, two- and three-year studies of the language curriculum are presented in Table 4-85 and Figure 4-4. Means were averaged over 10 sets of treatment effects in the nine one-year studies, four sets of two-year studies and two sets of three-year studies. Although all the treatment effects are positive, they fail to show the pattern of increasing gains demonstrated by the mathematics CAI curriculum.

Table 4-85

Summary of the 1-Year, 2-Year and 3-Year Studies of Language CAI

	Number of Studies Averaged			Mean Standardized Treatment Effects			Performance Level in Percentiles		
Tests	1YR	2YR	3YR	1YR	2YR	3YR	1YR	2YR	3YR
Language CST	10	4	2	.71**	.76**	.73**	76	78	77
CTBS Spelling	10	4	2	.14*	.05	.14	56	52	56
CTBS Mechanics	10	4	2	.22**	.27*	.25	59	61	60
CTBS Expression	10	4	2	.11	.05	.23	54	52	59

* $p < .05$.

** $p < .01$.

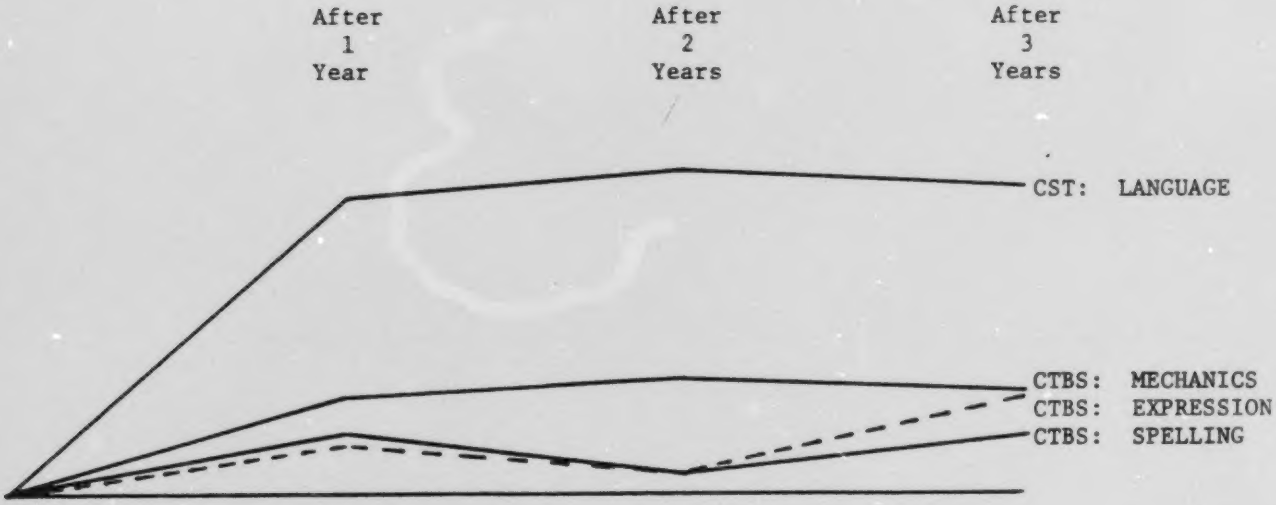

Figure 4-4 Language Treatment Effects over 3 Years.

When the treatment effects in Table 4-85 are compared with the one-year effects for students receiving reading CAI or reading-for-comprehension CAI in grade 4, year 4 (Table 4-83), the CTBS results for those students in one year equal or surpass the treatment effects averaged for CAI language across one, two or three years. The reading-for-comprehension CAI group is significantly better in language expression, and the reading CAI group put in a good, solid performance. Clearly there is overlap in the ability of the three verbally oriented CAI curriculums to produce results on CSTs and CTBS subtests in both reading and language. Although each of the three verbally oriented CAI curriculums has demonstrated some ability to help students perform better, they have yet to demonstrate the strong, overall, consistent effects achieved by the mathematics curriculum.

CAI vs No CAI

The within-CAI analyses reported in the first two sections of this chapter give the best estimates of treatment effects that we can obtain from the data. The randomized assignment of students to CAI curriculums--even when implemented with less than absolute success--assured the study of its best control groups. Two other control groups were used, however. Cohort controls were students who were in CAI schools one year earlier or later than CAI students and who were not given access to the CAI labs. Comparison students were in the same area of Los Angeles as CAI students, in two elementary schools without CAI facilities. Before we report on CAI effects when CAI students are contrasted with cohort controls or comparison students, we will explain the reservations we have about these regression analyses.

With regard to the cohort control analyses, by their very nature they cut across testing years. Although the school and teacher variables are better controlled than those for comparison schools, effects specific to the year of testing cannot be controlled. Earlier or later testing dates, the amount of time between pretesting and posttesting, the loss of time due to flu epidemics and other conditions specific to a school year may affect the findings. During posttesting at the end of year 3, students found the body of a young man shot to death in a suspected gang-related incident near the school playground of one of the CAI schools. For one week in that testing period conditions at the school were unlike conditions obtaining at any other period of the study.

Analyses involving CAI schools vs comparison schools suffer because of school differences. In three years of classroom observations, comparison-school students were found to spend more time on task overall, comparison teachers spent almost twice as much time teaching, and comparison teachers were rated higher by observers on teaching effectiveness. The smaller of the two comparison schools was a Title I school; more than two-thirds of the CAI students were from Title I schools.

With those reservations recorded, the treatment effects will be examined.

Mathematics

Table 4-86 presents an overview of the CAI treatment effects in mathematics for CAI students vs cohort controls and comparison-school students.

Table 4-86

Treatment Effects for CAI Students vs Cohort Controls and Comparison School Students: Mathematics

Grades	1 2 3 →	1 2 3 →
	CAI vs Cohort Controls	CAI vs Comparisons
CST	.80*	.76*
COMPUTATION	.51*	.15
CONCEPTS	.46*	.60*
APPLICATIONS	.38*	.87*

Grades	2 3 4 5 →		2 3 4 5 →	
	CAI vs Cohort Controls		CAI vs Comparisons	
	MM	RL	MM	RL
CST	1.26*	.46*	1.02*	.11
COMPUTATION	.70*	.08	.45*	-.03
CONCEPTS	.18	.11	-.03	-.02
APPLICATIONS	.28	.22	.29	.21

Grades	4 5 6 →		4 5 6 →	
	CAI vs Cohort Controls		CAI vs Comparisons	
	MM	RL	MM	RL
CST	1.11*	.57*	.28	-.20
COMPUTATION	.08	-.07	-.19	-.32
CONCEPTS	.20	.06	.09	.14
APPLICATIONS	.07	-.26	.04	-.11

*$p < .05$

In the cohort-control data we see a trend for the statistically significant effects to occur at the lower grade levels. It is difficult to know whether that is a meaningful observation or an artifact. The grade 4-6 CAI group had many difficulties: randomization problems, differential attrition, loss of students to the LAUSD desegregation plan. Forced to estimate a treatment effect for CAI students vs cohort controls, one might average the effects for mathematics CAI students to come up with 1.06 for the mathematics CST, .43 for CTBS math computation, .28 for concepts and .24 for applications. Those estimates are slightly lower, overall, than the three-year, within-CAI estimates in Table 4-82.

The comparison-school data repeat the pattern of more significant treatment effects in the lower grades than in the upper.

Reading and Language

Table 4-87 presents the treatment effects for CAI students vs cohort controls and comparison students on reading and language tests. One of the interesting things to notice is the differential performance of the RL group on reading CSTs as compared to language CSTs in these analyses. In the cohort control studies the RL group performs only half as well on reading CSTs as they do on language CSTs. The contrast is even more striking in the comparison school data. The language arts CAI curriculum teaches students something which helps to differentiate them from students without that curriculum when they are tested on the CSTs. That cannot be said as strongly for the reading curriculum.

Estimating overall treatment effects for CAI vs cohort controls with no CAI, we find the following: .44 for the reading CST, .22 for the CTBS

Table 4-87

Treatment Effects for CAI Students vs Cohort Controls and Comparison School Students: Reading and Language

Grades	2 3 4 5 →		2 3 4 5 →	
	CAI vs Cohort Controls		CAI vs Comparisons	
	RL	MM	RL	MM
READING CST	.56*	.23	.11	-.02
CTBS VOCABULARY	.41*	.34*	-.04	-.09
COMPREHENSION	.20	.17	-.27	-.21
LANGUAGE CST	1.06*	.45*	.46*	.11
CTBS SPELLING	.20	.20	-.13	-.05
MECHANICS	.11	.18	.12	.15
EXPRESSION	.22	.28	.08	-.03

Grades	4 5 6 →		4 5 6 →	
	CAI vs Cohort Controls		CAI vs Comparisons	
	RL	MM	RL	MM
READING CST	.32	-.15	.26	-.33
CTBS VOCABULARY	.03	-.33	.02	.14
COMPREHENSION	-.05	.11	.44	-.01
LANGUAGE CST	.66*	-.05	.70*	-.21
CTBS SPELLING	.11	-.11	.08	-.15
MECHANICS	.32	-.12	.27	-.21
EXPRESSION	.12	-.12	.12	-.11

$p < .05$

vocabulary subtest and .07 for comprehension. In language we find .86 for the language CST, .15 for CTBS spelling, .21 for language mechanics and .17 for language expression. The reading results may be compared with the results of the within-CAI three-year analyses in Table 4-84. They are not consistent. Language results for CAI vs cohort controls are more consistent with the within-CAI results in Table 4-85.

For the comparison school data, we note that most of the results for the RL group are positive, while most for the MM group are negative. On the average, the performance of the RL group is at least as good as the performance of the comparison school students.

Chapter VI

SUMMARY AND CONCLUSIONS

In part 4 of the Final Report we have been examining the effectiveness of drill-and-practice CAI curriculums at improving student performance in mathematics, reading and language arts. The statistical model underlying the basic analysis was reported in Chapter II. We learned that the basic regressions used sex, ethnicity, classrooms, pretests and CAI treatments to predict student outcomes both on standardized tests--the CTBS--and on curriculum-specific tests--CSTs--developed from the CAI curriculums. The CSTs were used to measure whether or not each of the CAI curriculums was successful in improving the performance of students on the material in which it was drilling them. The CTBS was used to measure the CAI curriculum's ability to change students' performance on standardized tests.

In Chapter III we saw the results of the within-CAI regression analyses done for the 12 one-year studies. We noted that first- and second-grade students were able to use the mathematics CAI curriculum effectively, that students in grade 3 used the mathematics and language curriculums effectively, and that students in grades 4-6 were able, for the most part, to use all three of the CAI curriculums: mathematics, language arts and reading. Some statistically significant treatment effects were noted at each grade level both on the curriculum-specific tests and the standardized tests.

Two findings from the one-year studies may be easily overlooked in the mass of data which were presented. One finding involved the second-grade use of fixed strands in the mathematics CAI curriculum. Ordinarily the mode of presentation in the mathematics strands curriculum was variable strands, where a problem in horizontal addition might be followed by one in vertical subtraction or number concepts. In fixed strands, problems received by the student were limited for the session to one strand selected by the teacher or CAI coordinator. In year 3, students in grade 2 were randomly selected within classrooms to receive part of their mathematics drill-and-practice via fixed strands. Although there were no statistically significant differences between the two groups, treatment effects consistently favored the fixed-strand group on the mathematics CST total, CTBS computation and, most strongly, concepts and applications. The findings suggest that the treatment effects for the mathematics strands curriculum might have been higher, had the study routinely allowed the provision of some CAI time in the fixed-strand mode. One simple procedure used in School 1 was to assign the student to fixed strands in that strand with the lowest placement score on the student's CAI record. Fixed strands were used for only part of the students' CAI time; the majority of the time was spent in variable strands. The use of fixed strands as described was somewhat akin to a tutorial session in the student's area of weakness. The combination of fixed and variable strands was not significantly better than variable strands alone, but it was consistently slightly better and was approved by CAI coordinators even though it was more work for them.

The second finding that could be overlooked in the one-year studies was the effectiveness rating of the newer reading-for-comprehension curriculum used in grade 4, year 4. The reading-for-comprehension curriculum differed from the older reading curriculum in one major way:

in every CAI session, the reading-for-comprehension curriculum presented a paragraph followed by five questions very similar in format to questions in reading comprehension subtests. When the performance of students assigned to the reading-for-comprehension curriculum (C), the reading curriculum (R) and the language curriculum (L) was compared to the performance of students assigned to mathematics CAI, the results show positive treatment effects for all three groups on reading and language tests. Group C put in the best performance on the reading comprehension subtest and a significantly better performance in language expression. Although the newer comprehension curriculum was only studied for one year without replication or longitudinal data, the one-year data suggests increased potential in the reading curriculum area. The paragraph questions also appealed to students, teachers and coordinators as an improvement over the straight reading curriculum.

In Chapter IV we examined the three longitudinal studies. We saw that the mathematics CAI curriculum was effective in improving students' performance in grades 1-3 both on CSTs and standardized tests. Students in grades 2-5 started CAI with two levels of mathematics and became increasingly differentiated into an MM group and an RL group. Their results in mathematics paralleled the results of the earlier CAI cohort. The results in reading and language were generally positive and ocassionally significant. The students in grades 4-6 experienced several problems which may have hurt their longitudinal study. The random assignment of students to curriculums was compromised when non-readers and some Hispanic students could not function in the reading and language curriculums.

Differential attrition rates over three years found brighter students leaving the MM and MRL groups and slower students leaving the RL groups. The fourth to sixth grade study was also hardest hit by the LAUSD desegregation plan when numbers of students in grades 5 and 6 moved out of CAI schools. Nevertheless, treatment effects in mathematics followed a pattern similar to the earlier longitudinal studies. Results in reading were not impressive. Language results were generally positive for both CSTs and CTBSs and were consistently significant for the language CSTs.

In Chapter V we estimated treatment effects for the three CAI curriculums and evaluated them in terms of their usefulness to the population of students in the study. The mathematics curriculum was found to have the widest applicability, capable of being used with students from kindergarten through sixth grade. Treatment effects for mathematics CAI students were averaged across grade levels to obtain a mean effect in one-, two- and three-year studies. For the CST data, mean treatment effects for the mathematics CAI students rose from .80 for one-year studies, to .91 for two-year studies, to 1.23 for three-year studies. CTBS computation data reflected the same pattern with mean treatment effects rising from .36 for one-year studies, to .56 for two-year studies, to .72 for three-year studies. Only the mathematics curriculum provided this pattern of increasing differentiation between groups over time. One is compelled to believe in the mathematics curriculum as a valuable resource in the area of mathematics training for elementary-school students.

The reading and language CAI curriculums were applicable at fewer grade levels and for fewer students within the appropriate grade levels.

One of the biggest drawbacks in the reading drill-and-practice curriculum is the pre-admission requirement of a third-grade reading ability. With newer technology a broader approach to reading may be possible and would be welcomed. As the reading and language curriculums now stand, Hispanics and non-readers in this study had difficulty making any progress, especially in the reading curriculum. Assignment of Spanish-speaking children and non-readers to either curriculum required large amounts of tutoring and translating time on the part of personnel in the CAI lab. Eventually the curriculums were judged unsuitable for some of those students. Other students readily topped out of the reading and, more frequently, the language CAI curriculums in grade 6.

On the CSTs the treatment effects for RL students over one, two and three years were .44, .52 and .42 for the reading CST and .70, .76 and .73 for the language CST. Treatment effects in reading were significant only for the first year of exposure to the CAI reading curriculum. All treatment effects on the language CST were statistically significant. There appears to be more "curriculum" in the language arts software than in the reading software. On the CTBS data, small positive effects--seldom significant after grade 4--appear to characterize the treatment effects for the RL groups in reading and language. Perhaps no strong patterns emerge because the curriculum was not broad enough and the students received only half as much of each curriculum as the MM students received in mathematics.

When CAI students were compared to their cohort controls in the same schools one year earlier or later, estimated treatment effects in three-year studies were very similar to the three-year within-CAI treatment effects in mathematics and language arts. Reading effects were less consistent.

In summary, we can say that each of the CAI curriculums proved its effectiveness, although some curriculums performed better than others. The mathematics curriculum showed strong promise in longitudinal studies. The reading and language CAI curriculums have less breadth but are both capable of helping students to improve. Computer-assisted instruction as defined in this study is a powerful tool for increasing students' skills in mathematics, reading and language arts.

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION:
THE ETS/LAUSD STUDY

LONGITUDINAL PATTERNS OF STUDENT ATTITUDES
IN A COMPUTER-ASSISTED INSTRUCTION CURRICULUM

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INTRODUCTION

The Coleman report (Coleman et al., 1966) made available information concerning the relationship between achievement and student attitudes. Subsequent studies also revealed correlations between achievement and attitudes such as attitudes toward school (Bloom, 1976; Jackson, 1968), attitudes toward reading (Engin, Wallbrown, & Brown, 1976; Roettger, Szymczuk, & Millard, 1980) and mathematics (Aiken, 1976), academic self-concept (Scheirer & Kraut, 1979), and academic locus of control (Crandall, Katkovsky, & Crandall, 1965; Lefcourt, 1976). These researchers were interested in the influence attitudes had on academic achievement.

In addition to their role as a mediating variable for achievement, positive attitudes should be an important outcome of schooling. Individuals develop much of their attitudes toward self during the period in which they attend school (Shaffer, 1979). Bloom (1976) has reported some evidence and speculated that positive attitudes in school have major effects on the individual's later mental health. McMillan (1980) has likened student attitude development to a basic skill, because of its prerequisite nature for effective cognitive learning and positive mental health.

Encouragement of positive attitudes toward achievement has been an important objective of compensatory education (Passow, 1974). Attitudes should be an integral part of the goals of the schooling process. Therefore, effectiveness of educational intervention should include an evaluation of its impact on student attitudes, independent of achievement.

The effectiveness of computer-assisted instruction (CAI) in demonstrating affective gains is not as clear as the evidence for cognitive gains. In an evaluation of the PLATO system, Swinton, Amarel, and Morgan (1979) found more positive attitudes among students using CAI at the elementary level than those not using it. Among junior high school students under the Stanford CAI system of drill and practice, no differences were found in attitudes compared to non-users (Smith, 1973). One investigation suggested that CAI improves the attitude of students (Hess & Tenezakis, 1973), another study at the community college level concluded that CAI does not ensure favorable student attitudes (Alderman, 1978).

CAI requires students to interact with a computer at a terminal, thereby providing an opportunity to exert some degree of control over their instruction. The Stanford, branching drill and practice may encourage persistence (something most computer users can empathize), because it adjusts the difficulty level so that students are always successful with some of the problems. Since persistence has been shown to be related to personal control (Lefcourt, 1976), students using CAI may develop more positive attitudes toward personal causation, i.e., become more internal about their successes.

The purpose of this study was to evaluate the differences in attitudes between CAI users and non-users. The curriculum provided drill and practice in math, reading, and language arts. CAI students were hypothesized to have more positive attitudes toward math and reading and to indicate more self-responsibility or control of their successes.

METHODS

Subjects

The sample of students for this study was selected from the data base of a longitudinal study of the effectiveness of CAI. The students attended urban schools designated to receive aid under Title I of the Elementary and Secondary Education Act of 1965. The students were predominantly from minority groups (Blacks 35%, Hispanics 44%) and there were slightly more females (55%) than males (45%).

The sample was selected because these students had participated in CAI from their fourth grade through their sixth grade and had relatively complete data. Students whose best language was not English were omitted from the study.

In an earlier study of achievement outcomes significant negative correlations between minority status and achievement were found (Griswold, 1981). Furthermore, White students had higher achievement scores than either Blacks or Hispanics. Whites and minorities were also split unevenly, approximately 25% versus 75%, respectively. For these reasons Whites were omitted from the study. Finally, some subjects were lost when the sample was selected for complete data, yielding a final N of 126.

Among this 126 were control students from schools and classrooms from the same district or within the CAI schools. Their assignment, in one sense, resulted in a conservative test of CAI effectiveness for the following reason. The non-CAI schools had an advantage over CAI schools, because more positive classroom observation ratings were made in the non-CAI schools (Ragosta, Holland, & Jamison, 1978). Thus, students from these schools came from better classrooms than did the CAI students.

CAI Treatment

The curriculum consisted of drill and practice exercises or strands in one of three subject areas: math, reading, or language. The range of difficulty was four or five grade levels. During a CAI session, a student received a random mixture of exercises from all the strands in the particular content area appropriate for the student's grade level, as determined at entry. Eighty percent mastery was the criterion for movement into the next level of difficulty. The assignment of students to within-CAI treatments was done at random. The students received CAI for 20 minutes per day: either all math, half math and half reading and language arts, or all reading and language arts.

Measures

The Iowa Tests of Basic Skills (ITBS), Form 5, Level 9 were administered in the fall, grade four. Vocabulary and Reading Comprehension subtests were combined as were Math Concepts and Problem Solving subtests. The results formed a reading and a math total raw score.

A Student Attitude Questionnaire, a variation of an instrument developed by Swinton, Amarel, and Morgan (1979), was administered every fall and spring. It purportedly measured attitude towards school, attitude towards math, reading, and language arts, self-esteem, and locus of control.

The fourth grade questionnaire items were constant throughout grades five and six. This set formed the basic instrument for the present study. The scale of the items was transformed so that a value of 3 was equivalent to a positive response, a 2 was an undecided response and a 1 was a negative response.

To identify the underlying constructs for separate evaluation, a principal components analysis was performed on 25 items of the questionnaire from all four years of the larger study (N = 1659). Those items that were excluded were negative in orientation (e.g., "Math is not my favorite subject.") and were shown to have caused confusion among the students (Griswold, 1981).

Using the SPSS subprogram FACTOR, a five factor solution explaining 100% of the variance resulted. In decreasing order of eigenvalue magnitude the factors were labeled as follows: Attitude towards Reading, Attitude towards School, Attitude towards Math, Perception of the Difficulty of Schoolwork, Perception of Responsibility for Success. The corresponding eigenvalues, rounded to two decimal places were: 3.26, 1.52, 1.13, .98, .56.

Attitude subscales were formed by summing items with factor loadings greater than .30 under each of the factors. The first through third subscales corresponded to each linear composite of items from factors one through three. A fourth subscale was formed by combining the composites of factors four and five. The latter subscale was redefined as Internal Responsibiltty for Success in School.

For each of the first five administrations of the questionnaire (the last was omitted because of missing data problems), four subscales of an attitude construct were computed for each student. They consisted of attitudes toward reading (LREAD), attitudes toward school (LSCHO), attitudes toward math (LMATH), internal responsibility for success (CAUSLPER). Each subscale was evaluated for internal consistency of its items using the coefficient alpha. The results indicated moderate to strong internal consistency ranging from .47 to .79 with a median of .67. Appendix A includes a list of the items composing each of the subscales.

Procedures and Analysis

The tests of hypotheses that more positive attitudes were associated with CAI were made with a 2 x 2 x 3 x 5 factorial analysis of variance (ANOVA) with repeated measures on the last factor. The three between subjects factors were CAI (Yes or no), sex, and achievement level. The within subjects factor was attitude (i.e., five administrations for each of the four subscales). The achievement factor was created by categorizing math and reading achievement into three levels: the upper, middle, and lower third of the raw score distribution from the fall, fourth grade ITBS. This design resulted in eight ANOVAS. One for math and one for reading achievement by each of the four attitude subscales. The SPSS subprogram MANOVA was used for the analyses.

The use of analysis of variance for a posteriori research is not without criticism when individual difference measures are categorized as a factor. A loss of statistical power results; there is an illusion of control of the variables; there is a tendancy to interpret significant relationships causally (Humphreys, 1978). The latter two issues can be avoided by explicit reporting of methods and results. The first issue is unavoidable, but makes for a more conservative statistical test, since the chance of rejecting the null hypothesis when it is true is reduced. Given these caveats, the partitioning of variances can be used to identify relationships; main effects can be interpreted as approximations to partial correlations (Humphreys & Fleishman, 1974).

RESULTS

The hypothesis that attitude among students receiving CAI is more positive than among non-CAI students as supported for two of the four subscales.

The ANOVAS indicated a main effect for CAI with attitudes toward reading, $F(1,114) = 18.02$, $p < .001$ with reading achievement levels and $F(1,114) = 17.35$, $p < .001$. A CAI main effect also was found for internal responsibility of success, $F(1,114) = 8.04$, $p < .01$ with reading achievement and $F(1,114) = 7.89$, $p < .01$ with math achievement. Tests of significance within cells for CAI using sequential sums of squares revealed significant differences across repeated measures of internal responsibility, but not for reading attitude. No main effects were found for attitude towards school or towards math.

No interactions with CAI were found, nor was there a difference with either achievement factor. Thus to explore further the nature of the CAI effects t tests were performed on unweighted CAI means at each administration of attitude toward reading and internal responsibility. The results for attitude toward reading were as follows, in order of administration: $t(158) = 2.63$, $t(166) = 3.87$, $t(178) = 4.14$, $t(171) = 3.69$, $t(156) = 4.24$, all $p < .01$. CAI mean attitude toward reading was significantly larger than non-CAI means. The results for internal responsibility were: $t(158) = 1.25$, n.s., $t(166) = 2.00$, $p < .05$, $t(178) = 2.75$, $p < .01$, $t(171) = 2.04$, $p < .05$, $t(156) = 4.12$, $p < .001$. CAI mean internal responsibility was significantly larger than non-CAI at all administrations after fall, grade four.

Significant main effects for achievement were found. When reading was the factor the main effects were with attitude towards reading, $F(1,114) = 4.79$, $p < .05$ and internal responsibility, $F(1,114) = 18.54$, $p < .001$. When math was the factor, the main effects were with attitude towards reading, $F(1,114) = 4.54$, $p < .05$, attitude towards school,

$F(1,114) = 4.10$, $p < .05$, and internal responsibility, $F(1,114) = 19.33$, $p < .001$. Inspection of the means suggested that the top third achievement level had the largest positive attitude for all significant main effects.

Sex differences across attitude subscales were found only for attitude towards school with either math or reading as the achievement factor. Females tended to be more positive in their attitudes toward school.

The three way interaction was significant for attitude towards school. The a posteriori evaluation made its interpretation moot.

CONCLUSIONS AND IMPLICATIONS

More positive attitudes toward reading were found among CAI students than among comparison students in non-CAI classrooms. This result may have been due to a systematic bias, since the CAI students' means were significantly greater than non-CAI even prior to CAI implementation. Cross-tabulations showed Hispanic students to be over-represented in the non-CAI group. Their bilingualism may have contributed to their lower attitudes toward reading relative to Blacks.

A greater sense of internal responsibility for success was found among CAI students. Prior to CAI implementation no differences were found between CAI and non-CAI means. Afterwards students in CAI had significantly greater means for self-responsibility. Furthermore the difference seemed to widen with continued CAI exposure.

The lack of differences with attitude towards math suggests that 20 minutes daily of CAI was not related to more positive attitudes. Math concepts became more difficult in fourth, fifth, and sixth grade and short periods of CAI may not ameliorate dislikes. More likely an explanation is that the CAI factor was not exclusively math drill and practice, but included reading as well. Similar arguments could be used for the attitude towards reading if it were not for the confounding by the large bilingual group in non-CAI.

As for no main effects for attitude toward school, it does seem unlikely that 20 minutes daily of an activity would make a difference in a general attitude such as this. Twenty minutes of confusion, or anxiety would seem to neutralize any positive attitudes toward school generated by CAI for its short duration.

The similarity of results regardless of using reading or math achievement as a factor suggests that the ability of these students has not yet differentiated into levels of reading and math ability. That is, a good student is not selectively better at math than reading, but rather he/she is good at all content areas.

The interesting and important finding with serious implications, was that CAI may prove helpful to minority students by improving the extent to which they feel in control of their successes. By interacting with a computer, a student is permitted a sense of control over the learning situation without the pressures from teachers and peers.

Although CAI students really have only a limited control of their learning session, the illusion of control is provided through logging on, then display of greetings or messages, entering answers and receiving reinforcing statements, followed by display of more questions. Such illusion of control has been shown to significantly improve performance in a variety of laboratory situations (Perlmuter & Monty, 1977).

Independent of CAI, attitudes were related to entry achievement level - higher levels of achievement were associated with a greater sense of control. This finding is consistent with the results of other similar studies (Lefcourt, 1976). Sex differences were anticipated in attitudes toward school. Females showed more positive responses.

Generally, CAI curricula have been shown to improve achievement. This is of obvious importance, but equally important is a need for students to understand realistically and objectively their capabilities (see Smith, 1973). From the present longitudinal evaluation, computer use by educationally disadvantaged students may enhance self-responsibility for academic success. The reality that the user - not the computer - is responsible for success and failure may be a windfall for students who tend to have less faith in their ability to control the course of their achievement.

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Appendix

Attitude Subscale Items

1. Attitude towards Reading

I am good at school

I am very proud of the way I read.

I am a good reader.

I feel very smart when I'm reading.

Reading is easy for me.

2. Attitude towards School

I like school.

I like spelling.

Writing letters is fun.

I am pretty happy these days.

I usually feel pretty good at school.

I like to be called on in class.

3. Attitude towards Mathematics

Math is fun.

I am good at math.

I am slow at doing math.

Math is the easiest thing I have to do.

I would rather do math than almost anything.

4. Internal Responsibility for Success

When I do well in language, it is usually because someone helped me.

When I do well in language, it is usually because I tried hard.

When I do well at school, it is because the work is easy.

When I do well at school, it is because I try very hard.

When I don't do my math very well, it is because the problems are too hard.

When I don't do my math very well, it is because I don't try hard enough.

PART 6*

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

ASSESSMENT OF THE EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION IN THE ETS-LOS ANGELES STUDY

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Part 6

Assessment of the Effectiveness of Computer-assisted Instruction in the ETS-Los Angeles Study*

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In what follows, an attempt was made to determine the impact on pupils' learning of the supplementation or replacement of part of their traditional program by computer-assisted instruction (CAI). The data on which the estimation of this impact was based were previously analyzed by Ragosta, Holland and Jamison. In this sense, no new data were reported here. However, the same body of data has been resorted and reanalyzed in ways that may make clear what was seen less clearly before (with, of course, the concommitant risk that some things seen clearly before are now lost).

This report is divided into four chapters: I. Validity of the Experiment and the Measurements, II. The Effects of Additional Computer-Assisted Instruction, III. The Effects of Replacing Traditional Instruction by Computer Assisted Instruction, and IV. Notes on Alternative Methods of Improving Achievement.

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*The analyses reported here were produced from data supplied to the author by the staff of the ETS/LAUSD study, Dr. Marjorie Ragosta, Director.

I. VALIDITY OF THE EXPERIMENT AND THE MEASUREMENTS

A. Experimental Validity. How valid was the ETS-LA experimental design, or rather, which of the many possible experimental comparisons are most valid?

The complex and comprehensive design employed in the ETS-LA study is probably familiar to the reader of this report. Figure 1 is presented as a convenient reminder of the patterns of controls, durations and grades that make up the experimental design.

1. Initial equivalence of groups.

Three types of control groups are present in the experimental design: within-CAI controls, cohort controls, and comparison school controls. The first group of controls (within-CAI) were pupils receiving CAI instruction but not in the subject (Reading, Math or Language) being evaluated. Thus, a group of pupils who studied only math by CAI could serve as a control group for those pupils who studied reading by CAI when reading performance was being evaluated. These control groups (hereafter referred to as Within-CAI Controls) have several highly desirable features: 1) they were initially randomly equivalent to the treatment groups, 2) they control for novelty effects in comparison with CAI treatment groups, and 3) they are drawn from the same classrooms as the CAI treatment groups thus being equivalent in all other respects (teacher type, etc.)

The Cohort Controls were groups of pupils like the CAI treatment groups but drawn from the classrooms following the

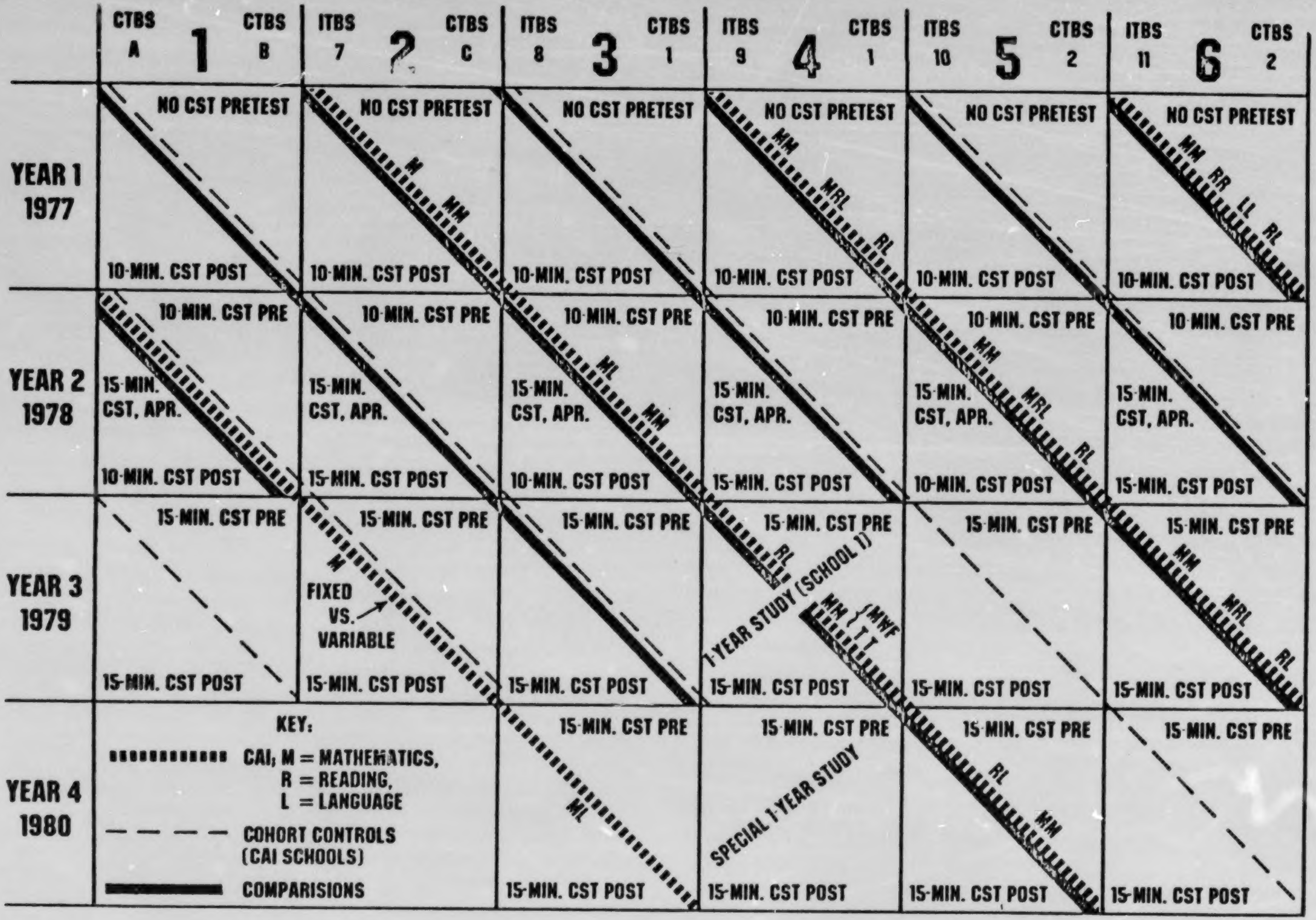
CTBS A 1 CTBS B
ITBS 7 2 CTBS C
ITBS 8 3 CTBS 1
ITBS 9 4 CTBS 1
ITBS 10 5 CTBS 2
ITBS 11 6 CTBS 2
YEAR 1 1977
YEAR 2 1978
YEAR 3 1979
YEAR 4 1980
NO CST PRETEST
10-MIN. CST POST
10-MIN. CST PRE
15-MIN. CST, APR.
15-MIN. CST POST
15-MIN. CST PRE
M
MM
MRL
RL
RR
LL
ML
FIXED VS. VARIABLE
1-YEAR STUDY (SCHOOL 1)
MM {MWF / TT
SPECIAL 1-YEAR STUDY
KEY:
CAI; M = MATHEMATICS, R = READING, L = LANGUAGE
COHORT CONTROLS (CAI SCHOOLS)
COMPARISIONS

Figure 1. The Design of Experimental Comparisons

treatment groups by one year. In spite of the many ways in which it can be argued that they should be similar to the CAI treatment groups, it is difficult to judge the difference a year makes; hence, their initial equivalence to the CAI treatment groups is problematic.

The third control condition comprises pupils in different schools altogether. The objections to its use as a control are many and obvious.

2. Accessibility and Attrition.

Over a period of either one or three years, pupils left the program. The reasons for leaving are unclear; it is unlikely that the left because of the kind of CAI treatment they received. It is highly implausible that they would leave a school due to the type of CAI groups (Math-Math vs. Reading-Language vs. Reading-Reading) they were assigned to. In advance of inspecting the data, I would have bet that attrition would have been strictly randomly distributed among the CAI curriculum groups, leaving the validity of the Within-CAI Control groups uncompromised. However, the pre-test means of the CAI curriculum groups differ significantly appearing to indicate that attrition was not random. For example, consider the CTBS Math Pre-test scores for Grade 6 students, Longitudinal Data, Total Math:

	CAI Group		
	Math-Math	MRL	Reading-Lang.
n:	32	34	28
$\bar{X}.$:	57.44	58.88	68.21
s_x:	24.00	22.14	18.52

The ANOVA F-ratio is 2.33 with df = 2.91; its percentile in the central F-distribution is approximately the 90th; thus, the probability that random attrition created discrepancies as large as these is only about .10. The F-ratio for the Reading pretest scores is 2.95, which is nearly significant at the .05 level.

In fact, at least two factors were at work. During the first year of the study, nonreaders and Spanish-speaking students who could not understand the reading curriculum were not forced to continue that assignment but were removed from the assigned CAI group and reassigned to Mathematics. Their data did not appear in the study's results. In addition, attrition over three years operated differently on the MM, MRL and RL groups: MM and MRL means on the inital pretest decreased over time and RL means increased over time. Of the two factors the greater contributor to initial differences was the first factor. One has little alternative but to take the fact of non-random accessibility and attrition seriously and worry about it. The details of this concern appear in the following section.

3. Ex Post Facto Correction.

Inaccessibility and non-random attrition of pupils across the CAI curriculum groups may have turned an unusually well designed experiment into a slightly problematic one. Where random assignment was never attained, or broke down, or was compromised by differentially mortality among treatment groups, the analysis of data falls into the gray area of ex post facto analysis of covariance adjustment. From all that is currently understood about the problem of attempting to correct the faults of non-randomness by covariance adjustment (Cronbach et al., 1977), one takes on these problems with deep regrets. There is no genuinely satisfactory solution, and analysis of covariance may undercorrect, overcorrect or correct perfectly depending on a variety of conditions (measurement reliability, discrepancies among groups on unobserved variables) about which one has typically no information. With the ETS-LA study, we find ourselves in such circumstances. I am inclined to take the analysis of covariance findings at face value, but they are worrisome precisely because they must be regarded as an ex post facto patching up of a randomized experiment that could not be maintained as fully randomized. In the end, perhaps, it is the findings and estimates of effects themselves that are the best evidence of their validity because they form patterns consistent with the interpretation that the method (CAI) was effective and that the Within-CAI control design assessed its effects reasonably validly.

The validity of the Treatment vs. Cohort Control design is even more problematic than that of the Within-CAI Control design, for the reason that assignment between CAI and Cohort Control groups was non-random in unknown ways.*

4. Control of Intructional Time.

In most respects, the Within-CAI comparison is the most internally valid experimental comparison available. But some have objected that such a comparison does not properly represent the choice between CAI and traditional instructional methods faced by the practitioner.

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*Designation of CAI vs. control years for cohort controls was somewhat arbitrary and might be regarded "as if " random; but even so, it was as if random at the school level at best and not at the level of pupils.

The consideration of this question opens up a deeper issue, which is best approached, perhaps, through a description of the schedule of activities in a typical CAI classroom. Students were randomly assigned to one of the CAI curriculum groups (viz., M, MM, RL, MRL). For a short period several times a week, either the entire class or a portion of it was sent to the CAI lab. When only a portion of the class was thus pulled out, those pupils who remained might study an academic subject or might engage in some less academic activity; exactly what they did varied from classroom to classroom and probably varied from week to week within the same classroom. In addition, all pupils were taught in basic subjects as a normal part of classroom work. An inspection of teachers' lesson plans would show several hours per week of traditional classroom instruction devoted to reading, math and language. Hence, the experiment must be regarded as a study of CAI supplementing traditional classroom instruction. (This point is important since it may not be reasonable to conclude that a successful supplement would be a successful steady diet; boredom effects would have to be considered, and particularly in the case of CAI, some of its benefits may depend on the opportunity to ask questions of human teachers that the machine can not answer.)

What kinds of instruction did pupils in various CAI curriculum groups experience? One can speculate with reasonable confidence. Suppose a teacher taught normally and sent the entire class to the CAI lab for 15-20 minutes several times a week. Then each pupil (regardless of CAI curriculum group) would receive, perhaps, 100-150 hours of reading instruction in a school year and about 75-100 hours of math instruction. In addition, pupils in the MM strand would receive about 15-20 min. daily of CAI instruction on top of classroom math instruction and more than pupils in the RL strand. Thus, with respect to math instruction, we have the following situation:

	Hrs./Yr. of Math Instruction in Traditional Classroom	Hrs/Yr. of Math in CAI Lab	Total Math Instruction
Pupils in CAI MM Strand	90 hrs.	50 hrs.	90 hrs.
Pupils in CAI RL Strand	90 hrs.	0 hrs.	90 hrs.

Under these circumstances, the CAI MM group receives 156% more instruction in math than the CAI RL group, which serves as its control group in the Within-CAI control group design. Clearly, under these circumstances the comparison of CAI MM with CAI RL on mathematics achievement must be regarded as an assessment of the effects of additional math instruction provided by computer over and above instruction in math in the regular classroom. If a decision maker were considering replacing school time spent in art or physical education with CAI math instruction over and above the school normal program, this experimental comparison would speak to his decision.

However, CAI MM vs. CAI RL would not speak to the question whether pupils' time spent in the CAI lab studying math is better spent there than in the classroom receiving traditional math instruction from their regular teacher. To answer this question, one must focus on the CAI vs. Cohort Control comparisons.

Which question ought one to answer: Traditional-plus-CAI vs. Traditional or Traditional-and-CAI vs. Traditional (implying that net instructional time is equated in the latter comparison)? There is no simple answer. But clearly, it can not be argued that one of these comparisons is proper and the other improper. It is easy to imagine a school district contemplating the implementation of CAI either as a means of increasing total time spent in basic skills instruction or as a replacement for some part of that time currently spent in traditional classroom instruction in basic skills. In the former case, the Within-CAI Control comparison will be most relevant; in the latter case, the CAI vs. Cohort Control comparison will be most relevant.

B. Measurement validity. Which outcome measure is better (i.e., more "valid," fairer to each program (CAI or Traditional), more relevant to the value that teachers and parents feel they are purchasing from the schools)?

The CTBS is a well-known survey-type test of achievement in basic skills (reading, math, language arts). The CST (Curriculum Specific Test) was constructed by the ETS project director from among the examples and exercises in the computer soft-ware for the CAI course. In the sense of practice on item forms (i.e., the obvious features of items such as horizontal vs. vertical addition), the CST favors the CAI subjects and might even be said to be "biased" in favor of the CAI group. For example, early item forms on the CST represented fractions in the form 2/3, a format dictated by the computer hardware but unfamiliar to control pupils who had been taught to deal with fractions in the form $\frac{2}{3}$. This problem was detected and corrected in a subsequent revision; but the possibility remains that less obvious superficial features remain in the CSTs and continued to favor the CAI group in a way that was unfair.

But charges of "bias" are not to be made lightly. Sometimes a "mere" matter of form in a curriculum actually represents improved pedagogy, and to remove it is to unfairly deprive the curriculum of one of its comparative advantages. So a judicious course must be steered between calling a test "biased" in favor of one curriculum versus reducing test coverage to the common core of items that may fail to credit a curriculum with its unique accomplishments.

I have not been able to perform a careful content analysis of the CSTs and the curricula in the present study. But based on a knowledge of the history of their production, I am inclined to feel that the findings on the CSTs overestimate the genuine value of the CAI program. On the other hand, the CTBS findings run a slight risk of underestimating the benefits of the CAI program. Survey-type standardized tests like the CTBS often fail to reflect accurately the content of the curriculum of a single school district; hence, their use in evaluating a new teaching method in a particular district may tend to underestimate its value. This problem could be serious in subjects like social studies where curricula differ greatly among school districts; it should be less severe in reading and math, particularly at earlier grades. Language arts curricula might be expected to differ more among districts than reading and math curricula. Thus, the CTBS can be expected to be more adequate in evaluating the effects of CAI on reading and math achievement than on language arts achievement.

The relevance of validity of the various measures of outcomes of instruction might be described in the following terms.

Type of Test

Subject	CTBS	CST
Math	well-matched with Math beyond the CAI curriculum.	well-matched with particular curriculum; less representative of Math more generally.
Reading	well-matched with Reading beyond the CAI curriculum.	well-matched with particular curriculum; less representative of Reading more generally.
Language	only moderately well-matched to both particular curriculum and Language Arts more generally.	well-matched with particular curriculum; less representative of Language Arts more generally.

C. Over-all Judgments of the Validity of the Design and the Tests.

For answering the question whether CAI is beneficial when it adds to the regular program of instruction of the school, the Within-CAI Control design is most relevant. For answering the question whether CAI is beneficial when used in place of part of the regular instruction time, the cohort-control design is most relevant. Although the former design was randomized but appeared to suffer from differential attrition (with poorer students dropping out of the RL and MRL curriculum groups) and although the latter design was not randomized, their findings after analysis of covariance adjustment on pretests are the best evidence available to answer the questions. Data from the Comparison School design will not be used.

The Curriculum Specific Tests were constructed in such a way that CAI students probably enjoyed an advantage on them for reasons unrelated to genuinely superior achievement. The Comprehensive Test of Basic Skills shares the well-known faults of standardized tests for curriculum evaluation; nonetheless, it is preferable to the CSTs in this instance and will be used exclusively in subsequent analyses of the ETS-LA experiment.

II. The Effects of Additional Computer-Assisted Instruction

A. One-year Study

Analyses in this section will be confined to data from "one-year" (i.e., not longitudinal) experimental comparisons. All comparisons are of the Within-CAI control group type. The pattern of experimental comparisons is complex; they come from different years and are made at different grades. They are shown in Table 1.

1. Mathematics Achievement. In Table 1 appear the experimental comparisons by grade and year in which double math periods (MM) were compared with single (M) or in which math instruction (either MM or M) was computed with instruction in reading (R), language (L) or both.

Table 1

Experimental Comparisons of CAI Instruction in Math (M), Reading (R) or Language (L)

	Year			
Grade	1*	2	3	4
2	MM v. M			
3		MM v. ML		M v. L
4			MM v. RL	M v. R or L
5		MM v. RL MRL v. RL		MM v. RL
6			MM v. RL MRL v. RL	

*Instruction in Year 1 lasted for only 1/4 school year.

Letting μ represent the effect of one unit (10 mins/day) of CAI math instruction and η represent the effects of two units (20 mins/day)--it can not be assumed that $2\mu = \eta$ -- then an experimental comparison such as M v. L estimates μ and a comparison such as MM v. M estimates $\eta - \mu$. In Table 2 appear the parameters estimated by each experimental comparison.

Table 2

Parameters Estimated by the Experimental Comparisons in Table 1

	Year			
Grade	1*	2	3	4
2	$\eta - \mu$ (?)*			
3		$\eta - \mu$		μ
4			η	
5	η μ			η
6			η μ	

*Instruction in Year 1 lasted only 1/4 school year.

The empirical findings were treated in the following manner. In each experimental comparison, the pretest-covariance adjusted posttest average for the curriculum group had the adjusted posttest average for the within-CAI control group subtracted from it and the difference was standardized by the within classroom among pupil standard deviation (after removing variance due to sex, ethnic group and classroom).

$$\Delta = \frac{\text{Adjusted } \bar{X}_{\text{Treatment}} - \text{Adjusted } \bar{X}_{\text{Control}}}{s_x}$$

The considerations that bear on this choice of a measure for expressing the findings of the experiment are several and complex; they are discussed in Glass, McGaw & Smith (1981). The measure Δ describes the average difference in experimental and control groups measured in units of the standard deviation of pupils' scores. The meaning of its algebraic sign (+ or -) is obvious; assuming normal distributions of scores (probably a safe assumption in the present instance), its magnitude can be interpreted in terms of the well-known properties of the normal distribution, e.g., if Δ = +1, then the average pupil's score in the experimental group exceeds 84% of the pupils' scores in the control group, and so forth. A special meaning that can be attached to a standardized mean difference measure of effect size in educational contexts derives from widely known norms for the rate of achievement growth per month of typical schooling. At most elementary school grades for most measures of educational achievement, the difference between the average pupil at the beginning of a grade and at the end of the same grade is about 1.0 standard deviation units. Hence, one month's typical instruction (or "time spent in school") accounts for a growth of about 0.10 standard deviation units. Hence, an instructional method that produces a +.50 effect size is responsible for benefits equal to those bought by five months of typical classroom instruction.

The estimates of parameters appear in Table 3 for the CTBS mathematics test, which included subtest scores for Computation, Concepts and Applications.

Table 3

Estimates of Parameters for CTBS the Subtests Math Computation/Math Concepts/Math Applications.

	Year			
Grade	1	2	3	4
2	$\hat{\eta} - \hat{\mu}$: .35/.33/-*			
3		$\hat{\eta} - \hat{\mu}$: .38/-.03/.04		$\hat{\mu}$: .27/.06/.10
4			$\hat{\eta}$: .27/.08/.10	$\hat{\mu}$: .43/.07/.04
5		$\hat{\eta}$: .37/-.02/-.09 $\hat{\mu}$: .19/-.27/.04		$\hat{\eta}$: .52/-.10/-.16
6			$\hat{\eta}$: .33/.05/.26 $\hat{\mu}$: .16/-.09/.21	

*CTBS Concepts & Applications subtests are combined at Grade 2.

Table 3 can be read as follows: in Grade 3 during Year 2 (in which MM was compared to M), the covariance adjusted standardized mean difference between MM(20 min./day) and M (10 min./day) of CAI instruction is .38 units on the Computations subtest, -.03 units on the Concepts subtest and .04 units on the Applications subtest. Thus, in math computation, the average third-grade pupil who received 20 minutes daily of CAI instruction scored higher by .38 standard deviation units than the average pupil who received 10 minutes of CAI math instruction daily. In math concepts, the average M pupil scored higher than the average MM pupil, but trivially so (by .03 standard deviation units).

a) Math Computation. The various estimates of μ and η in Table 3 can be combined to obtain over-all estimates.

The average of all the four different estimates of μ in Table 3 is +.29. The four estimates of η average is .37. Combining these yields an estimate of $\eta - \mu$ of

$$\hat{\eta} - \hat{\mu} = .37 - .29 = + .08.$$

But in the two instances in which MM and M were compared directly within the same classrooms (Grade 2, Year 1 and Grade 3, Year 2), the estimate of $\hat{\eta} - \hat{\mu} = (.35 + .38)/2 = .36$.

These estimates (.08 vs. .36) derived from two separate sources are somewhat disparate. Perhaps the discrepancy results in part from a confounding of treatment effects with grade level, since the .36 estimate of $\hat{\eta} - \hat{\mu}$ comes from data at Grades 2 and 3 and the .08 estimate from data at Grades 4, 5 and 6. The discrepancy can not be attributed confidently to such an interaction since the entire experimental design, of necessity, fell far short of a completely crossed factorial design.

There appear to be no "year" effects in the data for math computation, i.e., experiments in years 3 and 4 don't appear to have given systematically different estimates from those done in years 1 and 2. But, again, in so far as can be discerned in the incomplete design of Table 2, there appears to be an interaction of MM v. M comparisons and grade level. Hence, in what follows immediately, η and μ will be estimated separately for grades 2 and 3 and for grades 4, 5 & 6. The problem of what to do with the Year 1 data for Grade 2 is difficult to resolve. If instructional time is linearly related to amount learned, then perhaps the figures for Year 1 should be quadrupled since CAI instruction was given only for the months of February through April, or at least, the CTBS was administered in April. But multiplying .35 by 4 gives an absuredly large figure of 1.40 for the advantage of MM over M, a figure that is much larger than any other direct estimate of $\eta - \mu$ for a whole school year. It is difficult to know how quickly pupils moved through materials in the quarter year of CAI in Year 1; failing that knowledge and faced with the embarrassingly large 1.40, it seems wiser to take the .35 estimate at face value and not tamper with it.

From all data in grades 2 and 3, the one available estimate of μ is +.27. The two estimates of $\eta - \mu$ agree quite closely: .35 and .38; it seems sensible to replace them with their average, .36. The two estimates have the following implications:

$$\hat{\eta} - \hat{\mu} = .36$$

$$\hat{\mu} = .27,$$

imply that

$$\hat{\eta} = .36 + \hat{\mu} = .36 + .27 = .63.$$

Hence, at Grades 2 and 3, the effect of 10 min/day of CAI on math computation is .27 standard deviation units on the average; the effect of 20 min/day is .63 standard deviation units.

At grades 4, 5 and 6, the results look slightly different. The three available estimates of μ (the effect of 10 min/day) average .26. The four estimates of η (20 min/day) agree somewhat poorly (.27, .33, .37, .52) and their average is .37. Combining these two estimates yields an estimate of the effect of the second daily 10 min instructional period of

$$\hat{\eta} - \hat{\mu} = .37 - .26 = .11.$$

But an argument could be made that the Grade 5, Year 2 and Grade 6, Year 3 experiments are to be preferred in estimating $\hat{\eta} - \hat{\mu}$ since MM and M were applied to the same classrooms within each experiment. Basing the estimate only on these two experiments yields

$$\hat{\eta} - \hat{\mu} = (.37 + .33)/2 - (.19 + .16)/2 = .18.$$

This figure agrees nicely with the over-all estimate.

Hence, at Grades 4, 5 and 6, the effect of 10 min/day CAI on math computation is .26 standard deviation units on the average; the effect of 20 min/day is .37 standard deviation units.

Although the effects of 10 min/day of CAI instruction is greater at Grades 2 and 3 than at Grades 4, 5 and 6, at either level the effect of 20 min/day is from one and one-half to twice as large as the effect of 10 min/day.

b) Math Concepts.

There is no evidence of any treatment by grade level interaction on achievement in math concepts, so the analyses that follow immediately will ignore grade level. Grade 2 in Year 1 is eliminated since math concepts and applications were not tested separately.

Type of Estimate	Value	Grade	Year
$\hat{\mu}$	.06	3	4
$\hat{\mu}$	-.27	5	2
$\hat{\mu}$	-.09	6	3
$\hat{\eta}$	.08	4	3
$\hat{\eta}$	-.02	5	2
$\hat{\eta}$	-.10	5	4
$\hat{\eta}$	.05	6	3
$\hat{\eta} - \hat{\mu}$	-.03	3	2

These effects are consistently small, and worse, mostly negative. The estimates of η and μ can be formed by simple averaging of the individual estimates:

$$\begin{bmatrix} \hat{\mu} \\ \hat{\eta} \end{bmatrix} \begin{matrix} = -.10 \\ = .00 \; . \end{matrix}$$

The difference $\eta - \mu$ estimated in this manner is

$$\hat{\eta} - \hat{\mu} = .00 - (-.10) = +.10.$$

The direct experimental estimate of $\hat{\eta} - \hat{\mu}$ is -.03. The average of these two estimates is +.03.

These slight ambiguities can be cleared up by forming a set of simultaneous linear equations that can be solved by methods of least square estimation, as follows:

$$\begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ 0 & 1 \\ -1 & 1 \end{bmatrix} \qquad \begin{bmatrix} \hat{\mu} \\ \hat{\eta} \end{bmatrix} \qquad \begin{bmatrix} .06 \\ -.27 \\ -.09 \\ .08 \\ -.02 \\ -.10 \\ .05 \\ -.03 \end{bmatrix}$$

Denoting the left-most matrix by $\underline{X}$ and the right-most by $\underline{Y}$, the estimates are obtained from

$$\begin{bmatrix} \hat{\mu} \\ \hat{\eta} \end{bmatrix} = (X^T X)^{-1} \cdot X^T Y.$$

The solution is as follows:

$$\begin{bmatrix} \hat{\mu} \\ \hat{\eta} \end{bmatrix} = \begin{bmatrix} -.07 \\ -.02 \end{bmatrix} .$$

These results can be taken in one of at least two ways: (1) the CAI math instruction for 10 min/day confuses ($\hat{\mu} = -.07$) pupils at the conceptual level but the confusion is removed with another 10 min/day so that they are left where they started ($\hat{\eta} = -.02$); or (2) the CAI math instruction has no added benefits at all at the conceptual level and the small numbers (-.07, -.02) merely reflect random or noisy perturbations in the evaluation system. I favor the second interpretation.

c) Math Applications

The estimated effects and the parameters estimated for math applications are as follows:

Type of Estimate	Value	Grade	Year
$\hat{\mu}$	.10	3	4
$\hat{\mu}$	.04	5	2
$\hat{\mu}$	.21	6	3
$\hat{\eta}$	.10	4	3
$\hat{\eta}$	-.09	5	2
$\hat{\eta}$	-.16	5	4
$\hat{\eta}$	.26	6	3
$\hat{\eta} - \hat{\mu}$	.04	3	2

Again, this set of numbers and parameter estimates can be treated as a system of linear equations and solved by the methods of the previous section:

$$\begin{bmatrix} \hat{\mu} \\ \\ \hat{\eta} \end{bmatrix} = (X^T X)^{-1} . X^T Y \begin{bmatrix} .07 \\ \\ .04 \end{bmatrix}$$

Thus, the effect of CAI instruction in math on math applications is essentially zero whether given for 10 min/day or 20 min/day.

d) Summary of Findings for Mathematics.

Covariance Adjusted Effect Sizes
Classified by Type of Math Achievement,
Grade Level & Amount of Instruction

	Area of Math Achievement					
	Computation		Concepts		Applications	
Amount of CAI Instruction per day	Grades 2&3	Grades 4,5& 6	Grades 2&3	Grades 4,5& 6	Grades 2&3	Grades 4,5& 6
10 mins.	.27	.26	-.07	-.07	.07	.07
20 mins.	.63	.37	-.02	-.02	.04	.04

2. Reading Achievement.

The design of one-year experiments assessing CAI reading instruction with an off-strand instructional program is presented in Table 4.

Table 4

Experimental Comparison for
CAI Reading Instruction

	Year			
Grade	1*	2	3	4
4	MRL v. MM RL v. MM		RL v. MM	R v. M
5		MRL v. MM RL v. MM		RL v. MM
6	RR v. MM RL v. MM		MRL v. MM RL v. MM	

* In Year 1, instruction lasted only one quarter of the school year (Feb. - April).

If ρ stands for the effect of 10 min/day of CAI reading instruction and θ is the effect of 20 min/day, then the experimental comparisons in Table 4 provide estimates of these parameters as indicated in Table 5. Note: In the MRL strand, reading instruction is for a total of 25 minutes per week or 5 minutes per day. Denote the effect of 5 min/day of CAI reading instruction by ψ.

Table 5

Parameters Estimated by Experimental Comparisons in Table 4

	Year			
Grade	1	2	3	4
4	ψ ρ		ρ	ρ
5		ψ ρ		ρ
6	θ ρ		ψ ρ	

The estimates of the effects of these parameters, again in the form of covariance adjusted standardized mean differences, appear in Table 6 for reading vocabulary and comprehension.

Table 6

Effect Sizes from Experimental Comparisons (Table 4) and the Parameters Estimated (Table 5) for Reading Vocabulary/ Reading Comprehension.

		Year		
Grade	1	2	3	4
4	$\hat{\psi}$: .04/-.04 $\hat{\rho}$: .28/.23		$\hat{\rho}$: .25/.26	$\hat{\rho}$: .26/.18
5		$\hat{\psi}$: .03/-.25 $\hat{\rho}$: -.03/-.09		$\hat{\rho}$: .23/.31
6	$\hat{\theta}$: .26/.45 $\hat{\rho}$: .28/.51		$\hat{\psi}$: .51/-.06 $\hat{\rho}$: .45/.03	

a) Reading Vocabulary

There are seven estimates of the effect of 10 min/day CAI instruction on reading vocabulary in the data in Table 6. When averaged, these estimates show the following trends across years and grades:

Average Estimates of ρ By

Year

1	2	3	4
.34	-.03	.35	.24

Grade

4	5	6
.26	.10	.37

There are differences to be noted here, viz., all the way from -.03 to .37, but the differences do not look like reasonable trends. The "best year" for CAI reading vocabulary was the third, and the "best grade" is the sixth, but the fifth is worse than the fourth. The variability is more confusing than orderly and conclusions about interactions of CAI effectiveness with grade level or year of the study would be unwise. The variability of effects of CAI on reading vocabulary in Table 6 is distressingly large (from -.03 to +.51) and can not be accounted for by anything simple and obvious.

The average of the three estimates of ψ is +.19, but to obtain it one had to average .04, .03 and .51 (a case of the average not being very "average").

Averaging the seven estimates of ρ in Table 6, we obtain

$$\hat{\rho} = .25.$$

The single available estimate of the effect of 20 min/day CAI instruction on reading vocabulary (from Grade 6 - Year 1) is

$$\hat{\theta} = .26.$$

Is 10 min/day of CAI instruction really as effective as 20 min/day, as reflected by $\hat{\rho} = .24$ and $\hat{\theta} = .26$? I doubt it. The estimate of θ is even more dubious because it came from a Year 1 experiment, the "year" that lasted only from February to April. (But to add to the confusion, notice that $\hat{\rho}$ for Grade 6 - Year 1 is larger than the average of all other estimates).

I am inclined to treat the single 20 minute (RR) experimental comparison and the three 5 minute (MRL) comparisons just like the other

10 minute (R) comparisons and average all 11 estimates of the effect of CAI on Reading vocabulary.

Conclusion: $\hat{\rho}$ = .23 for reading vocabulary, with the qualification that the estimates of experimental effect are quite variable around this average figure, ranging from -.03 to +.51.

b) Reading Comprehension

The reasoning that led to the estimate of ρ for reading vocabulary applies in many respects to the estimation of the effect of CAI instruction on reading comprehension.

The estimates of ρ for reading comprehension in Table 6 range from -.25 to +.51, and thus are even more variable than the estimates of the effect on reading vocabulary. The inspection of the data for trends across years and grades produces the following results:

Average Estimates of ρ By

Year

1	2	3	4
.29	-.17	.08	.25

Grade

4	5	6
.16	-.01	.23

No sensible trends for either Year or Grade Level are apparent. The three estimates of ψ, the effect of 5 min/day CAI instruction, average to

$$\hat{\psi} = [-.04 + (-.25) + (-.06)]/3 = -.12.$$

The seven estimates of ρ, the effect of 10 min/day CAI, average to

$$\hat{\rho} = [.23 + .26 + .18 + (-.09) + .31 + .51 + .03]/7 = .20.$$

The single estimate of θ, the effect of 20 min/day of CAI, is

$$\hat{\theta} = .45.$$

This is definitely a trend in the expected direction, and the distinction among number of minutes of instruction per week accounts for some of the troublesome variability in the various estimates of effects. For example, the 11 estimates in Table 6 range from -.25 to +.51 with a variance of .06. But the (weighted) average variance of effects within the 5 min/day and the 10 min/day categories (20 min/day is, of course, not considered since it has only one estimate of effect) is .04. Thus, the instructional time distinction reduces variability in estimates of effects by 40%.

c) Summary for Reading Achievement

Effect Sizes Classified by Reading Vocabulary & Comprehension, Grade Level & Amount of Instruction

Amount of Instruction	Reading Vocab. (Grades 4-6)	Reading Comprehension (Grades 4-6)
5 min/day for one year	.23	-.12
10 min/day for one year	.23	.20
20 min/day for one year	.23	.45

3) Language Arts Achievement.

The design of experimental comparisons for assessing the effects of CAI language appears in Table 7. Beside the designation of the On and Off-strands, there appears the parameter estimated by the comparison (either λ_5, λ_{10} or λ_{20} for 5 min/day, 10 min/day or 20 min/day of language instruction).

Table 7

Experimental Comparison for CAI

Language Instruction

	Year			
Grade	1*	2	3	4
3		ML v. MM: λ_{10}		L v. M: λ_{10}
4	MRL v. MM: λ_5 RL v. MM: λ_{10}.		RL v. MM: λ_{10}	L v. M: λ_{10}
5		MRL v. MM: λ_5 RL v. MM: λ_{10}		RL v. MM: λ_{10}
6	LL v. MM: λ_{20} RL v. MM: λ_{10}		MRL v. MM: λ_5 RL v. MM: λ_{10}	

*Instruction in Year 1 lasted only from February through April.

a) Achievement in Spelling, Mechanics & Expression.

The estimated effect sizes corresponding to the comparisons in Table 7 appear in Table 8.

Table 8

Effect Sizes for the Experimental Comparisons in Table 7 for Language Arts Achievement: Spelling/Mechanics/Expression.

	Year			
Grade	1	2	3	4
3		$\hat{\lambda}_{10}$: -.12/.10/.01		$\hat{\lambda}_{10}$: .51/.31/.12
4	$\hat{\lambda}_{5}$: +.08/-.01/-.07 $\hat{\lambda}_{10}$: .34/.21/.21		$\hat{\lambda}_{10}$: .03/.41/.33	$\hat{\lambda}_{10}$: .48/.44/.20
5		$\hat{\lambda}_{5}$: -.16/.16/-.25 $\hat{\lambda}_{10}$: .22/.16/-.38		$\hat{\lambda}_{10}$: -.09/.21/.33
6	$\hat{\lambda}_{20}$: -.10/.08/-.09 $\hat{\lambda}_{10}$: .11/.18/.12		$\hat{\lambda}_{5}$: -.13/.07/.17 $\hat{\lambda}_{10}$: -.03/.21/.20	

First, consider all estimates $\hat{\lambda}_{10}$ and average them to determine whether trends exist for grade level or year:

Average $\hat{\lambda}_{10}$ for Grades & Years,

(Spelling/Mechanics/Expression).

Year

1	2	3	4
.23/.20/.17	.05/.13/-.19	.00/.31/.27	.30/.32/.22

Grade

3	4	5	6
.21/.21/.07	.28/.35/.25	.07/.18/-.02	.04/.20/.16

Inspection of the average effects across either grades or years shows no consistent trends. Both grade and year can probably be safely ignored in the analyses that follow. In the following table, the estimated effects for 5 min/day, 10 min/day and 20 min/day of CAI language instruction are compared:

Average Estimated Effect Sizes:

	Spelling	Mechanics	Expression	(# of Effects)
5 mins/day, λ_5:	-.07	.07	-.05	(3)
10 mins/day, λ_{10}:	.16	.25	.13	(9)
20 mins/day, λ_{20}:	-.10	.08	-.09	(1)

The above averages are indeed small, but a trend may be lurking in them. First, the three 20 min/day figures probably ought to be eliminated from consideration since they are based on a single experimental comparison performed in Year 1. The 5 min/day averages look to be genuinely zero. The 10 min/day averages remain. They are small (.16 for spelling, .25 for mechanics, .13 for expression) but they hint at a reliable non-zero effect. Consider the graph of the effects in Figure 2.

These are the 27 effect sizes for CAI language instruction when instruction was conducted for 10 min/day for one school year.

The arrow in Figure 2 marks the average of the 27 effect sizes. However, one of the 27 is clearly an "outlier,"viz., the value of -.38 for Grade 5 - Year 2 (cf., Table A-8, p. 412 in Dixon and Massey, 1957). Elimination of the outlier raises the average to +.18. It seems advisable to remove the aberrant point even though the reasons for its uniqueness are not known. The 26 remaining effect sizes can be averaged and arranged in a table in which type of language skill and amount of instruction are represented.

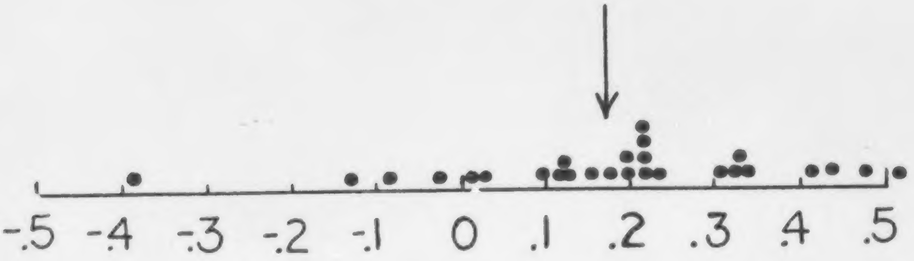


Figure 2. Effect Sizes for CAI Language Arts Instruction.

b) Summary for Language Arts.

	Spelling	Mechanics	Expression	Average
5 mins/day:	-.07	.07	-.05	-.02
10 mins/day:	.16	.25	.19	.20
Average:	.04	.16	.07	.09

These data appear to indicate no added benefits for 5 minutes/day of language arts CAI but consistent small effects for 10 minutes of instruction.

B. The Longitudinal (Three-Year) Studies

In Table 9 appear the estimated experimental effects on math, reading and language achievement from the two three-year longitudinal studies using the CAI On-strand vs. CAI Off-strand design. The source of the data upon which the estimates are based is the report of test scores in the final report.

The sensitivity of standardized language arts tests to local curricula has often been questioned; moreover, the success of computers in promoting rote learning as opposed to conceptual learning has frequently been suggested. Both phenomena appear to be reflected in Table 9. There is a solid benefit of between a half and three quarters of a standard deviation for math computation. The addition to the regular instructional program of 20 minutes each day for three years of CAI teaching in math appears to have added about .70 standard deviation units of achievement to the average student's skill in math computation. The benefits of the CAI instruction on his knowledge or understanding of math concepts and applications is less clear.

Despite the likely mismatch between the language subtests and the language arts CAI curriculum, there appear to be small positive benefits accruing for 10 min./day of language instruction. The variability in reading effects across the two studies is so great as to preclude any final statement on the benefits of the long term use of the reading program.

Some the the relationships between the control and CAI groups are depicted in Figure 3. One sees that the average Math CAI pupil scores about 76 percent of the control pupils on Math computation after three years.

Table 9

Effects of Additional CAI Instruction in Basic Skills on Achievement in Math, Reading & Language for Three-year Longitudinal Treatment Study: CAI On-strand vs. Off-strand Design.

Achievement Test	CAI On-strand of 20 min/day vs. CAI Off-strand ($n_1 = n_2 = 30$) Grades 4-6.	CAI On-strand of 20 min/day ($n_1 = n_2 = 30$) Grades 3-5.	Mean Effect Size
Math:			
Computation	Δ = .64	.79	0.71
Concepts	.28	-.10	0.09
Applications	.58	-.05	0.26
Reading:			
Vocabulary	.58	-.04	0.27
Comprehension	-.24	.24	0.00
Language:			
Spelling	.22	.06	0.14
Mechanics	.09	.40	0.25
Expression	.22	.24	0.23

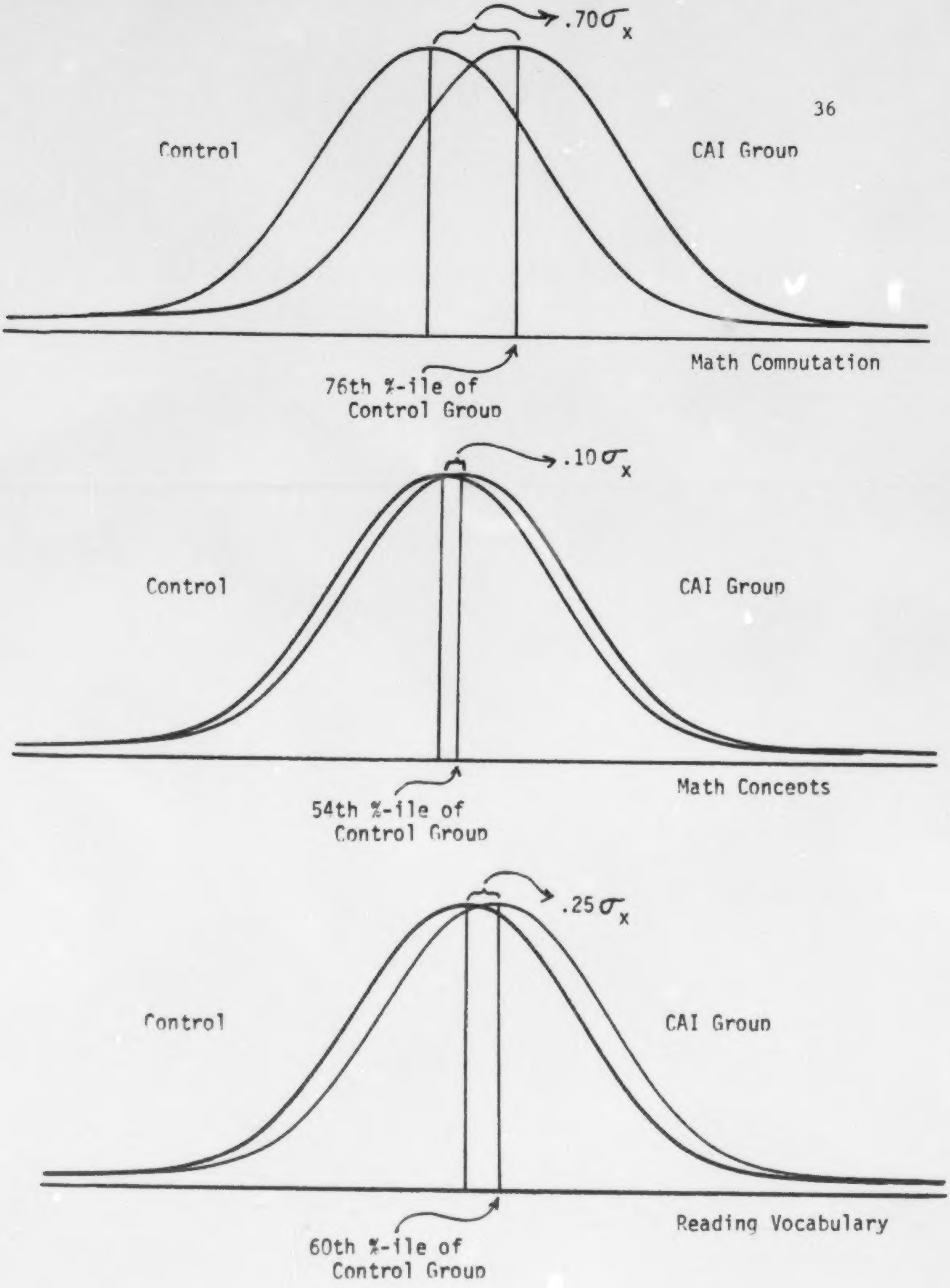


Figure 3. Effects of CAI on Math Computation, Math Concepts and Reading Vocabulary from the Three-year Longitudinal Study

C. Summary of Effectiveness Analyses

The data analyzed here on the effects of CAI instruction on reading, math and language arts are summarized in this section. Findings are not reported separately by year of the study, since this distinction made no difference in the size of the effect produced by CAI. Likewise, grades are lumped into Grades 2-3 and Grades 4-6, because the possibility of an interaction of effectiveness with grade exists for math achievement. Amount of instruction per day (5, 10 or 20 minutes) was an important variable and is represented in the table. See Table 10.

Table 10 is already a highly condensed table in which details are ignored (one hopes none of them are very important) for the sake of coming to an understandable conclusion. In spite of the condensation in Table 10, one's eye is still distracted by incidental features. Perhaps the findings can be made clearer by an "enhancement" of the picture, in the manner of computer enhanced photographs. Table 11 is based on Table 10; it was produced by exaggerating the "signal" in Table 10 and damping the "noise." What is signal and what is noise is difficult to judge. The following rules were used to enhance Table 11: (a) negative numbers were changed to zero, (b) most positive numbers were rounded to the nearest .05 number, (c) grade-by-treatment interactions were ignored (by averaging over grades) since they were based on less solid evidence, (d) other things equal, large sample results should count more heavily than small sample results.

Table 10

Effect Size (in Standard Deviation Units) for Various Amounts of Computer-Assisted Instruction for Achievement in Mathematics, Reading & Language Arts

			Math						Reading				Language					
			Computation		Concepts		Applications		Vocabulary		Comprehension		Spelling		Mechanics		Expression	
Mins./day	Years	Grades:	2-3	4-6	2-3	4-6	2-3	4-6	2-3	4-6	2-3	4-6	2-3	4-6	2-3	4-6	2-3	4-6
5	1		--	--	--	--	--	--		.23		-.12		-.07		.07		-.05
10	1		.27	.26	-.07	-.07	.07	.07		.23		.20		.16		.25		.19
20	1		.63	.37	-.02	-.02	.04	.04		.23		.45		--		--		--
10	3			--		--		--		.27		.00		.14		.25		.23
20	3			.71		.09		.26		--		--		--		--		--

(Where cells are blank, there were no data.)

Table 11

"Enhanced" Version of Table 10

		Math			Reading		Language		
Mins/day	Years	Comput.*	Concept	Appl.	Vocab.	Compre.	Spell.	Mechan.	Express.
10 min.	1	.25	.00	.00	.25	.20	.15	.25	.20
20 min.	1	.50	.00	.00	.25	.45	--	--	--
10 min.	3	--	--	--	.25	.00	.15	.25	.25
20 min.	3	.70	.10	.25	--	--	--	--	--

* Math Comp.

Mins/day	Grades 2-3	Grades 4-6
10 min.	.30	.25
20 min.	.65	.35

III. THE EFFECTS OF REPLACING TRADITIONAL INSTRUCTION BY COMPUTER ASSISTED INSTRUCTION: FINDINGS FROM THE COHORT CONTROL DESIGN

The comparison of the achievement of pupils studying by CAI with the achievement of pupils who were taught one year earlier or later in the same school is called a Cohort Control Design, and it addresses a different question from the findings of the Within - CAI Design. Since total instructional time was equated between the CAI groups and the Cohort control groups, the CAI vs. Cohort comparisons measure the effect of replacing some time (10 or 20 mins. two to five times a week) in traditional instruction by the same amount of time with CAI. (The findings reported earlier measured the effect of adding CAI instruction to the existing curriculum, which was otherwise unchanged.)

The Cohort design was earlier judged inferior to the Within - CAI design; to repeat what was written about the validity of the Cohort design earlier in this report, "The validity of the CAI vs. Cohort Control design is even more problematical than that of the Within - CAI Control design, for the reason that assignment between CAI and Cohort Control groups was non-random in unknown ways. Designation of CAI vs. control years for Cohort control was somewhat arbitrary and might be regarded 'as if' random; but even so, it was as if random at the school level at best and not at the level of pupils."

The validity of the Cohort design is probably not as bad as was earlier indicated. A feature of the CAI schedule permits estimation of and correction for most of the weaknesses of the Cohort design. Within a CAI classroom, pupils were randomly assigned to CAI curriculum groups, such as M, R, L, RL and so forth. When a CAI M-group is compared with a Cohort control group from the same school but from an earlier (non-CAI) year, the comparison is confounded by a large number of unknown non-random influences plus it is presumed to benefit unfairly from the "novelty" effect of CAI (i.e., pupils may attend to instruction more closely only because it is incidentally associated with the excitement of computers). However, the CAI R-group, which studies Reading but neither math nor language by CAI, is subject to both confounding influences (non-random nonequivalence and novelty) to the same degree as the CAI M-group. Consequently, in assessing the impact of CAI on math achievement, the CAI R-group's math scores provide an excellent correction for the confounding influences affecting the CAI M-group and Cohort control comparison. Hence, where possible in the analyses that follow, a CAI vs. Cohort comparison will be corrected by subtracting the "effect" of CAI for the comparison of an equivalent group studying a different curriculum by CAI and its Cohort control. The validity of the resulting corrected effect should be quite respectable.

In Tables 12-14 appear the estimated effect sizes arranged by subject tested (mathematics, language and reading), the year of the four-year ETS study in which effects were assessed (either year #3 or #4), the duration of the CAI instruction with the treatment group (1, 2 or 3 school years), and the school grade level (2-5).

A. Mathematics Achievement.

In Table 12 appear the findings for mathematics, reported on three subtests (computation, concepts and applications, the latter two subtests being combined at grades 1 and 2). All of the effect sizes at grades 4 and 5 are controlled, in the sense that there is a within-CAI randomly equivalent curriculum group (either RL, R or L) that is compared to the same Cohort control. The average effect sizes for the five experimental comparisons at grades 4 and 5 before correction by subtracting the estimated effects of invalidity from the RL, R or L vs. Cohort comparisons are as follows:

Table 12. Effect Sizes for Mathematics: (Computation/Concepts/Applications) from CAI vs. Cohort Design

Grade of Achiev. Meas.:	Year of the Study 3 Duration of CAI Instruction 1 yr.	 2 yrs.	4 1 yr.	 2 yrs.	 3 yrs.
2	MO v. 00: (.35/-.04/*) OM v. 00: (.44/.45/*)	MM v. 00 (.67/.50/*)			
3			M v. Coh. (.29/.03/.14)	M v. Coh. (.61/.44/.19)	M v. Coh. (.14/.04/-.24)
4		MM(3) v. Coh. (.78/.40/.54) RL(3) v. Coh.** (.20/.17/.25) MM(2) v. Coh. (.49/.28/.59) RL(2) v. Coh.** (.24/.28/.45)		M v. Coh. (.72/.60/.36) R v. Coh.** (.23/.51/.27) L v. Coh.** (.40/.18/.31)	
5				MM v. Coh. (.77/.29/.36) RL v. Coh.** (.17/.45/.51)	MM v. Coh. (.70/.18/.28) RL v. Coh.** (.08/.11/.22)

Grade 1, Year 2: (.37/.12/*)

*At grades 1 and 2, the Concepts & Applications sections of the CTBS are combined.

**These effect sizes estimate the combined effects of experimental internal invalidity and CAI novelty.

	Uncorrected Average Effect, Grades 4 & 5
Computations	.69
Concepts	.35
Applications	.43

When these figures are corrected by subtracting the RL, R or L vs. Cohort effects, the following averages are obtained:

	Corrected Average Effect Sizes, Grades 4 & 5
Computations	.49
Concepts	.08
Applications	.08

These figures agree reasonably well with the estimated effects in Tables 10 and 11 for 20 mins/day of CAI for instruction of duration 1 to 3 years, the largest discrepancy being a larger effect on Applications in the previous analyses.

The estimates of effects at grades 1-3 in Table 12 are uncontrolled in the sense that they lack within-CAI curriculum groups (RL, R or L) vs. Cohort control comparisons for correcting for nonequivalence and novelty effects. These estimates of effects differ further from those at the higher grades in that the Concepts and Applications subtests are merged. The average effect sizes on the subtests are as follows:

	Uncorrected Average Effect Sizes, Grades 1-3
Computations	.41
Concepts & Applications	.13

These figures show the same trends as the comparable figures in Table 10 and agree reasonably well, though not precisely, with them.

B. Reading Achievement.

In Table 13 appear the estimated effect sizes for the Reading subtests of Vocabulary and Comprehension. The M and L CAI group vs. Cohort control effect sizes can be used to correst the R and RL vs. Cohort control effects. Each of the five CAI Reading effect sizes in Table 14 can be corrected in this manner; the R vs. Cohort effect for grade 4 - year 4 was corrected by the average of the effects for M vs. Cohort and L vs. Cohort. The average corrected effect sizes for the Reading subtests are as follows:

Reading Subtest	Corrected Average Effect Size
Vocabulary	.14
Comprehension	.15

These effects are very nearly zero.

C. Language Arts Achievement

In Table 14, the estimated effects appear for the Language subtests of Spelling, Mechanics and Expression. With respect to the assessment of language outcomes, the M and R CAI vs. Cohort control effects can be used to correct the RL or L vs. Cohort control effects for the nonequivalence of the two latter groups and the novelty advantage of the CAI groups over the Cohort control groups. Unlike in Table 12, all of the CAI language effects can be corrected. Their average for each subtest is as follows:

Language Subtest	Corrected Average Effect Size
Spelling	-.03
Mechanics	.25
Expression	.15

Table 13: Effect Sizes for Reading: (Vocabulary/Comprehension) from CAI vs. Cohort Design

	Year of Study		
	3	4	
	Duration of CAI Instruction		
Grade	2 yrs.	2 yrs.	3 yrs
4	RL(3) v. Coh. (.11/.34) MM(3) v. Coh.** (.18/.29) RL(2) v. Coh. (.59/.68) MM(2) v. Coh.** (.22/.34)	R v. Coh. (.35/.25) M v. Coh.** (-.05/-.02) L v. Coh.** (.25/.16)	
5		RL v. Coh. (.50/.44) MM v. Coh.** (.30/.27)	RL v. Coh. (.41/.20) MM v. Coh.** (.34/.18)

**These effect sizes estimate the combined effects of experimental internal invalidity and CAI novelty.

Table 14: Effect Sizes for Language: (Spelling/Mechanics/Expression) from CAI vs. Cohort Design

	Year of Study		
	3	4	
	Duration of CAI Instruction		
Grade	2 yrs.	2 yrs.	3 yrs.
4	RL(3) v. Coh. (-.16/.66/.56) MM(3) v. Coh.** (-.01/.20/.43) RL(2) v. Coh. (.03/.94/.92) MM(2) v. Coh.** (.09/.47/.31)	L vs. Coh (.07/.60/.38) R v. Coh.** (.00/.54/.52) M v. Coh.** (-.24/.36/.34)	
5		RL v. Coh. (.21/.57/.34) MM v. Coh.** (.33/.43/.29)	RL v. Coh. (.20/.49/.18) MM v. Coh.** (.20/.47/.16)

**These effect sizes estimate the combined effects of experimental internal invalidity and CAI novelty.

These agree generally with the effect sizes reported in Table 10 for the Language subtests primarily in their being quite small.

D. Summary of Effects of CAI Replacing Traditional Instruction

The findings in Tables 12-14 may have been too incomplete (in a factorial design sense) to detect trends in effect-size magnitude across grades or years of the study or duration of instruction and separate these possible trends from interactions. Where trends could be explored, none emerged, e.g., in Mathematics at grades 3 and 5 where duration of instruction trends might have shown up. Hence, in the following summary of effect sizes, distinctions among years of the ETS study, school grades and duration of instruction in years have been dropped. The figures in Table 15 have been slightly "enhanced" through averaging (e.g., Grades 4 & 5 with Grades 1-3 in math) and rounding so as to disspell the impression of accuracy.

Table 15: Corrected Effect Sizes Estimated from the CAI vs. Cohort Control Design

Subject Tested	Corrected Effect Size
Mathematics	
Computations	.45
Concepts	.10
Applications	.10
Reading	
Vocabulary	.15
Comprehension	.15
Language	
Spelling	.00
Mechanics	.25
Expression	.15

IV. NOTES ON ALTERNATIVE METHODS OF IMPROVING ACHIEVEMENT

The following alternatives to CAI as a means of increasing pupil achievement will be considered: (1) reduction in class size, (2) tutoring, (3) instructional television, (4) teacher training, (5) calculators.

The instructional method of choice will be that one which is most cost-effective. In the pages that follow, much is reported about the effectiveness in terms of pupil achievement of several alternatives to CAI. However, these few notes fall far short of a defensible cost-effectiveness analysis since no attempt was made to evaluate costs. While the following data on the effectiveness of various methods of instruction may help place the CAI effectiveness data in a slightly more informative context, closure on the question must await a more serious attempt at cost-effectiveness analysis, (of the type, for example, that Jamison (1982) performed on class size reduction vs. CAI).

1. Reduction in Class Size.

School classes, which typically number about 25 pupils today in the elementary grades, can be made smaller by hiring more teachers, by putting aides (paraprofessionals) in the classroom, or by using older pupils to teach or tutor younger ones. Research has shown that interventions of any of these types results in improved pupil achievement, and that no one of these interventions has been shown to be any more effective than the others (Glass, Cahen, Smith and Filby, 1982).

In Figure 4 appears a graph of the relationship between school class-size and pupil achievement. The relationship was empirically determined by the findings of over 700 comparisons of achievement in classes of varying sizes from nearly 80 studies published since 1910. The actual shape of the curve is based on a subset of 110 comparisons taken from 14 studies that applied good experimental principles in the design of the comparison of smaller and larger classes.

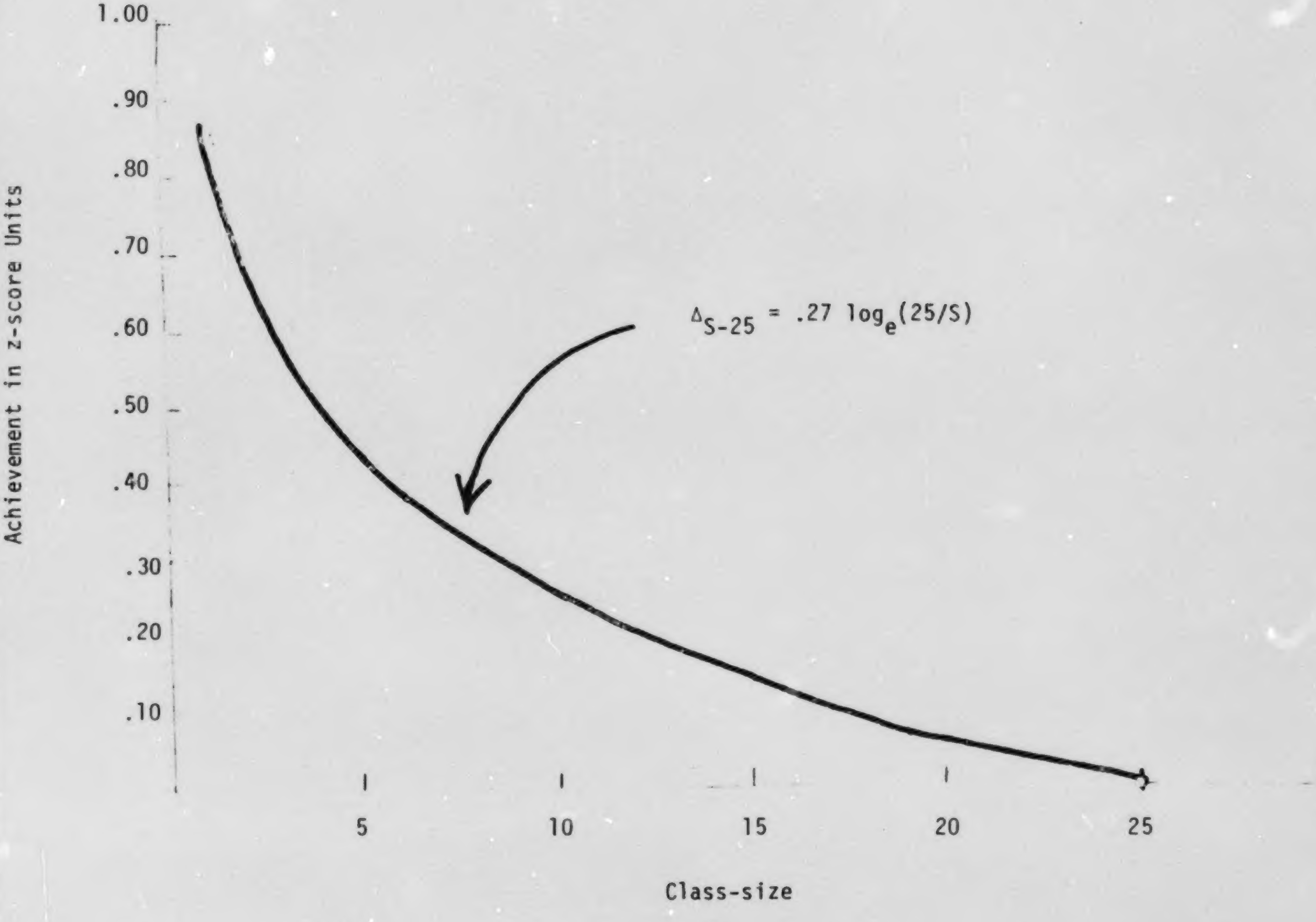
The curve in Figure 4 is interpreted as follows: if a class of size 25 is assumed to have average achievement ($z = 0$), reduction of class-size by 5 pupils will raise achievement by about .05 standard deviation units, reduction to class-size 15 will increase achievement by about .15 standard deviation units, and so on.

Several points must be noted about these findings because they bear on the comparison of these data with the ETS-LA findings for CAI:

a) no evidence was found that the basic relationship in Figure 4 was different for different subjects taught (e.g., reading, math), different grades (elementary vs. secondary) or for "teachers" of different levels of experience.

b) all of the data underlying Figure 4 were based on experiments in which small classes replaced rather than supplemented large classes, i.e., the small class was taught for the same amount of time as the large class, as opposed to a design in which pupils normally in large classes were given additional instruction in small groups. Thus, the findings in Figure 4 for reduction in class-size are more comparable to the ETS-LA cohort comparisons than to the Within-CAI comparisons.

Figure 4. Graph of the Relationship Between Instructional Group Size and Achievement.



c) The duration (in hours and weeks) of the experiments that gave rise to the data underlying Figure 4 varied greatly, from as little as 1 hour to as many as 900. Even though no relationship was observed between the duration of the study and the strength of the relationship between class-size and achievement, I have tabulated the study durations below:

Hrs Instruction	No. of Δ's
1	9
3	1
9	3
25	8
30	18
40	1
54	2
60	1
100	5
120	19
180	2
700	36
900	3

Just what is to be made of this failure to discern a relationship between the number of hours in small group instruction and the size of the benefit of small classes is troubling, particularly for cost-benefit analysis. Obviously, the no relationship finding can not be extrapolated to the limit or else one would be forced to conclude that one minute of instruction in a one-on-one tutorial is the equivalent in benefit (.87 standard deviation units) of a whole school year of tutorials. Clearly this can not be so.

2. Tutoring.

"Tutoring" (i.e., one-on-one instruction) can be regarded as a special case -- the limit -- of class-size reduction. Studies of its effectiveness in relation to instruction in groups were covered in the previous section on the effects of class-size reduction. If the class-size and achievement curve in Figure 1 is to be believed, a pupil who is tutored individually scores .87 standard deviation units higher on an achievement test than he would if taught in a group with 24 other pupils.

Hartley (1977) investigated the benefits of tutoring in a meta-analysis of the effects on mathematics achievement of methods of individualizing instruction. She identified 68 effect size measures from about 25 studies of the effects of supplemental tutoring (i.e., in addition to large group traditional classroom instruction). Only 5 effect size estimates were available for replacement tutoring (i.e., tutoring in place of traditional large group instruction). The average and the standard deviation of the effects were as follows:

Effect Sizes for Tutoring

Type of Tutoring	Average Effect Size	St. dev. of effect sizes	No. of Effect Sizes
* Supplemental	.61	.70	68
Replacement	.42	.26	5

The "Replacement" findings should not be taken too seriously since they are based on so few studies. The "Supplemental" average effect is not directly comparable to the tutoring estimate of .87 from the class-size analysis since supplemental studies were excluded from the class-size study by the nature of the question addressed there.

Hartley reported the following data on the amount of tutoring given pupils in these studies: the average number of hours of instruction was 37.4 hrs. (with a standard deviation of 43.9 hrs.) -- hence, they were more heterogeneous in terms of hours of instruction than they were long! The average length of the experiments in weeks was about one semester: 17.0 weeks (standard deviation = 12.2 weeks). Moreover, the correlation between the duration of application of the experimental treatment and the effect size was _r_ = -.01.

Hartley also collected data on computer-assisted instruction in mathematics. Where CAI supplemented regular large-group instruction, the following comparison of CAI and tutoring was observed:

	Effect Sizes by Type of Supplement	
	CAI	Tutoring
Average Effect	.47	.61
St. dev. of Effects	.58	.70
No. of Effect Sizes	75	68

Here the superiority of Tutoring over CAI is of the order of about .15 standard deviation units. If one restricts attention to experiments in which pupils were _randomly assigned_ to experimental and control groups, the Tutoring advantage widens and the typical CAI effect becomes much more like that observed in the ETS-LA study:

	Effect Sizes from Randomized Designs by Type of Supplement	
	CAI	Tutoring
Average Effect	.31	.58
St. dev. of Effects	.44	.74
No. of Effect Sizes	11	52

The above figures seem credible. They show an effect of about .30 standard deviation units for supplemental CAI and about .60 for supplemental tutoring. It should be pointed out that the average number of hours of instruction in the CAI studies summarized to obtain the .30 effect size was 22.1 hrs. vs. 37.4 hrs. for the tutoring study. If the evidence of Hartley's analysis on the relationship of duration of instruction and benefits can be set aside momentarily and the assumption made that amount of supplemental instruction should be linearly related to effect size, then the .30 effect of CAI could be inflated by the factor 37.4/22.1 = 1.69 to obtain a CAI effect for a period of instruction comparable in length to that for tutoring; CAI for 37.4 hrs. would equal 1.69 (.30) = .51 standard deviation units. Now the comparison of CAI and Tutoring effect sizes looks more like .51 vs. .58, a smaller difference.

There were other relationships in Hartley's data that argue that CAI and Tutoring are even more similar in their impact on achievement than they first appear to be. The CAI effect is slightly negatively correlated with grade level and negatively correlated with pupil IQ. Tutoring effects are less strongly negatively correlated with grade level, and they are positively correlated with pupil IQ. When the effect sizes for CAI and Tutoring are covariance adjusted and estimated at grade 6 for low ability pupils, (Hartley, 1977, p. 81) the effect sizes are

CAI = .431,

Tutoring = .427.

Several different figures have been given above; they are repeated here for clarification:

Average Effect Sizes

	CAI	Tutoring
1. Replacement of traditional classroom instruction.		.87 (from Glass et al., 1982) .42 (from Hartley, 1977)
2. Supplement of traditional classroom instruction.	.47	.61
3. Supplemental & randomized design.	.31	.58
4. Same as #3 but instructional time equated.	.51	.58
5. Same as #3 but with IQ and grade level equated, (Low IQ, Grade 6).	.43	.43

Precisely what is to be made of these different figures is hardly obvious. The replacement effect size for tutoring might be somewhere between .40 and .90! For some reason I think a figure nearer .40 is more defensible than one near .90. Therefore, the effect size for Tutoring as a replacement of traditional large group instruction in math is +.50 standard deviation units.

The figures for the effect of tutoring used as an add-on supplement to traditional large group classroom instruction agree more closely among themselves than the two replacement estimates did: the effect sizes ranged from .43 to .61. The average is a good summary: therefore, the effect size for tutoring as a supplement to traditional large group instruction in math is +.50 standard deviation units.

Many estimates of CAI effects in math are of the order of .50 standard deviation units. Considering line 5 of the above table and a lot of other things, my guess is that the benefits for math of equal amounts (in minutes) of CAI and tutoring are nearly equal.

3. Instructional Television.

Chu and Schramm (1967) reviewed 207 experiments comparing instructional television (ITV) with traditional classroom teaching; they could see no clear trend in these studies indicating that pupils learned more with ITV than by traditional teaching methods.

Carnoy (1975) attempted a cost-effectiveness analysis of ITV, but it is difficult to infer from his report whether or not he believes ITV is more effective than traditional classroom instruction. The Hagerstown, Maryland data reported in Chu and Schramm are cited and analysed by Carnoy,* but his attitude toward them is ambivalent. So is mine, but they indicated the following:

Hagerstown: Effects of ITV on Mathematics Achievement (Iowa Test of Basic Skills) for Primary School Pupils (Data in G. E. Units)

Year	Grade 3	Grade 4	Grade 5	Grade 6
1958 (Before ITV)	3.59	4.43	5.26	6.49
1959 (Yr 1 of ITV)	4.06	4.97	5.77	6.83
1960 (Yr 2 of ITV)	4.18	5.01	6.13	7.17
1961 (Yr 3 of ITV)	4.30	5.08	6.19	7.26

For the calculation of effect-size measures from the above data we can safely assume a standard deviation of 1.0 years for elementary school pupils in math; this is the figure typically observed.

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*Carnoy also reported ITV effectiveness data from El Salvador; information needed to translate the findings into standardized effect sizes was missing. I haven't been able to use the data.

The above data can be treated as a cohort design with Grade 3 in 1958 being essentially the same pupils as in Grade 4 in 1959 and so forth. The 1958 (Before ITV) averages can serve as control group expectations. For example, comparison of Grade 3-1959 against Grade 3-1958 is an evaluation of the effect of one year of ITV: (4.06 - 3.59)/1.0 = +.47 standard deviation units. Likewise, the comparison of Grade 4 - 1959 with Grade 4 - 1958 gives an estimate of the benefits of a year's ITV: (4.97 - 4.43)/1.0 = +.53 standard deviation units. There are a total of six such one-year effect sizes. Similarly, there are four comparisons that assess the effect size from two years study under ITV, e.g., Grade 4 - 1960 vs. Grade 4 - 1958 equal to (5.01 -4.43)/1.0 = +.58 st. dev. units.

In the following table, the effect sizes reflecting the benefits of ITV as a replacement of traditional classroom instruction are reported; the reported figures are averages of the multiple experimental comparisons corresponding to one, two and three years exposure to ITV.

No. of Years Under ITV	Average Effect Size: Math
One	+.53
Two	+.70
Three	+.86

Carnoy estimated that these benefits were bought at a cost of $31 per pupil per year.

4. Teacher Training.

Gage and Giaconia (1981) reviewed the findings of four experiments on the effects of teacher training on pupil achievement. They reported that specialized teacher training programs (training in pedagogic methods dealing mainly with management of large-group instruction) produced achievement gains in experimental groups that exceed control group gains by more than .5 standard deviations. I have been able to obtain only two of the four reports: Good and Grouws (1979) and Anderson, Evertson and Brophy (1979).

My calculations confirm an effect size of about +.5 on SRA mathematics subtest in the Good and Grouws experiment favoring the pupils of the group of teachers who received special training (two 90 min lectures and reading of a 45-page manual). I haven't detected major flaws in this study. The difference in pupil performance (on the Metropolitan Reading Test) for specially trained vs. control teachers in the Anderson, Evertson and Brophy study is of the order of +.90 standard deviations favoring the pupil of the specially trained teachers. This study was not as well done as the Good and Grouws study. Treatment and control conditions were not mixed within schools; hence, the experimental design employed the equivalent of assigning schools (not teachers) to the two conditions compared. Nine schools and 27 teachers participated. No indication was given of how schools were assigned to the experimental conditions; one doubts seriously that the assignment was random -- researchers seldom omit mention of random assignment when they have been lucky enough to bring it off. The investigators apparently hoped to compensate for the deficiencies of design by administering a pretest (Metropolitan Readiness Test) to pupils and correcting (via analysis of covariance) the posttest reading average for any lack of pretest equivalence. The pretest data showed the following:

	Mean	St. dev.	n
Exper. Group	68.98	6*	17
Control Group	65.74	7.55	10

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*Rough estimate

These data show a +.48 standard deviation difference on the pretest between the experimental and control pupils, favoring the former. Analysis of covariance never completely corrects for such non-equivalence (Cronbach et al., 1977); plus it can only correct for measured nonequivalence and in this instance we have reason to worry that some important non-equivalences between experimental and control groups were not measured.

5. Electronic Calculators.

At least for math teaching (but perhaps for other subjects as well), hand-held electronic calculators (EC) may be cheapter and as effective as CAI. Many experiments on the effectiveness of EC in math instruction have been performed. Roberts (1980) reviewed most of them and concluded that EC instruction is generally beneficial as a supplement or superior to traditional classroom instruction when tested as a replacement. More than 80% of the literature is reported in dissertations not otherwise available. I have been able to obtain reports of five EC experiments. Their findings are summarized in the following table:

Results of Experiments on the Effectiveness of Instruction by Electronic Calculator (vs. Traditional Classroom Instruction)

Study	Hrs. Instruction	Grade	Design Quality	Type of Test	Effect Size: $\frac{\bar{X}_{EC} - \bar{X}_{con.}}{s_x}$
Gaslin (1975)	50	9	Good	Curriculum specific: "Fractions"	-.36
				"Frac."-Retiontion	.00
				Transfer test	+.08
Hohlfeld (1974)	3	5	Good	Curriculum specific: multiplication.	+.25
Schnur & Lang (1976)	5	7	Probably Good	Standardized test of computation.	+.92
Schafer, Bell & Crown (1975)	2	5	Probably good	ETS math comp. test	+.21*
Creswell & Vaughn (1979)	40	9		Curriculum specific: decimals & percents	1.34*

*Electronic Calculator group allowed to use calculators on the posttest!

The findings of these five studies are inconsistent. Effect sizes range from -.36 to +1.34; they average +.35, but there is no good reason to average them. There is no pattern of effects consistent enough to use as a basis for comparison with other interventions.

6. Summary

The data on the effectiveness of the various methods of instruction discussed in this section may help to put the CAI data in perspective. Overall, several of the different intervention strategies appear to produce results superior to traditional classroom instruction. A final assessment of the cost effectiveness of each strategy awaits the further work of economists.

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COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

A. An Evaluation of the Costs of Computer-Assisted Instruction

Henry M. Levin and Louis Woo

B. Towards a Meta Cost-Effectiveness Analysis of Educational Interventions

Henry M. Levin and William Seidman

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*This appeared as Part 7 of M. Ragosta, P. W. Holland, and D. T. Jamison Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study, Final Report to the U. S. National Institute of Education, April 1982.

COMPUTER-ASSISTED INSTRUCTION AND COMPENSATORY EDUCATION: THE ETS/LAUSD STUDY

A.

AN EVALUATION OF THE COSTS OF COMPUTER-ASSISTED INSTRUCTION

October 1979

by

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"An Evaluation of the Costs of Computer-Assisted Instruction"

Abstract

The purpose of this paper is to estimate the costs and cost-feasibility of utilizing computer-assisted instruction (CAI) for compensatory education. Cost data were collected from an experiment on the effectiveness of CAI that had been established in Los Angeles and sponsored by the National Institute of Education. Based upon the resource ingredients approach to measuring costs, it was found that up to three daily ten minute sessions of drill and practice could be provided for each disadvantaged child within the present allocation of funds from Title I of the Elementary and Secondary Education Act of 1965. If the computer system were shared between two schools, the higher costs would permit only two daily sessions.

Costs were also estimated for a more advanced CAI system, and somewhat surprisingly the costs were in the same range. This finding reflects the very heavy costs of "software" which do not seem to decline with more advanced technologies. Also, it is possible that the latter technology will be found to be more effective at the same cost level. However, since comparative effectiveness data between the CAI approach and other instructional strategies are not readily available, such cost-effectiveness comparisons will have to be deferred until some future date.

AN EVALUATION OF THE COSTS OF COMPUTER-ASSISTED INSTRUCTION

INTRODUCTION

Various educational technologies such as educational radio, educational television, and computer-assisted instruction have been proposed in recent years as partial solutions to both the problems of rising educational costs and the failure of the educational system to impart basic skills to disadvantaged youngsters. The logic of the cost-saving aspects of educational technologies is conditioned heavily upon the assumption that the high labor costs of education can be reduced by substituting relatively lower-cost capital inputs without sacrificing educational results. The view that certain educational technologies can improve the quality of educational results for disadvantaged youngsters is premised on the fact that such approaches as computer-assisted instruction can be individualized to take account of the particular strengths and deficiencies of the learner.

These assumptions about the comparative advantages of replacing some portion of traditional classroom instruction with a more capital-intensive educational technology would seem especially pertinent to the case of computer-assisted instruction (CAI). Recent technological breakthroughs in computers and particularly the advent of mini-computers and inexpensive memory devices have both expanded the capability and flexibility of computers with respect to their instructional applications while reducing their costs considerably. Also, CAI permits a large variety of methods for individualizing instruction according to the actual performance of the learner. For example, a computer-based curriculum can be designed to provide automatically additional problems for a student in any area in which he is not performing according to some pre-set standard, or it can be arranged in particular sequences of instructional tasks that emphasize his special instructional needs.

Despite the promise of educational technology in improving educational outcomes and reducing costs, there is little supporting evidence of a rigorous nature on either the relative costs or educational results.[1] In response to this evaluative deficiency, the National Institute of Education decided to undertake an experimental study of computer-assisted instruction in order to evaluate its effects on the improvement of reading, language skills, and arithmetic operations of elementary school children. The experiment was initiated in the Fall of 1976 on the basis of a research design that was prepared by the Educational Testing Service (ETS) and implemented in the Los Angeles Unified School District (LAUSD). Known as the ETS/LAUSD Study on Computer-Assisted Instruction and Compensatory Education, the study was intended to ascertain both the effects of a particular computer-based instructional system and curriculum on student test scores in three subject areas as well as the costs for replicating this particular system.

With respect to educational effectiveness, the research design was constructed in order to ascertain the effects on test scores in reading, arithmetic, and language arts of the "drill and practice" curriculum of the Computer Curriculum Corporation (CCC) among students at different elementary grade levels. The evaluation was arranged to determine the effects of 10 minute daily sessions of CAI on student achievement.

Comparisons of test results for disadvantaged students are being made according to the number of daily sessions of CAI, the subjects in which CAI sessions were given, and the number of years in which students received CAI. Hopefully, the studies of effectiveness will reveal the educational impact of this particular CAI approach across subject, grade levels, amounts of exposure, and different types of students (race, sex, ethnicity, social class origin, and so on).[2]

Obviously, the evaluation of the effectiveness of this CAI approach does not address the issue of costs. Given its focus on the educational needs of disadvantaged students, there are two questions pertaining to costs that arise. The first question is based upon the assumption that funding for special educational services for disadvantaged students is derived primarily from special categorical aid for that purpose, such as that received under Title I of the Elementary and Secondary Education Act of 1965. Therefore, it is important to know if the CAI can be provided within the budget that is available for these compensatory educational services for disadvantaged youngsters. Second, it is important to know if the CAI approach can improve the educational proficiencies of disadvantaged students at costs that are similar or less than those associated with other instructional alternatives.

The first issue is one of cost-feasibility. If the costs of this CAI approach exceed the funds available for instructional purposes for disadvantaged youngsters, it will not be within the boundaries of feasibility. The second issue is one of cost-effectiveness. Even if the CAI can be provided within the present budgets for compensatory education, it should be adopted only if it provides better results relative to its costs than existing alternatives.

Cost-feasibility can be examined by evaluating the costs of the CAI instruction and ascertaining whether it is within the budgetary allocations provided for compensatory education by Title I of the Elementary Secondary Education Act of 1965 or by various state and local compensatory programs. Cost-effectiveness comparisons can only be made by comparing both the results of the CAI approach and its costs with the results and costs of other instructional alternatives. While this study can establish its costs, it is not designed to pursue its effects. However, the overall CAI experiment on which this study is based will provide rather sophisticated estimates of test score results associated with student exposure to different amounts of CAI and different subjects. Accordingly, the costs that are estimated in this study can be combined with the experimental effects of the CAI for cost-effectiveness comparisons with other instructional approaches.

In this paper we will estimate the replication costs of the CAI approach used in the LAUSD/ETS experiment, that is the cost of replicating that system in other school settings. In doing this we will limit those costs only to ones that are associated with the delivery of the CAI instruction, while omitting costs that are tied uniquely to the experimental status of the present system. That is, we are concerned with the costs of introducing this particular CAI approach into other schools outside of the present experimental situation. At the same time, we are concerned with modifications of the experimental CAI that might affect costs. In particular, there exists a later version of the present computer that is more advanced. The cost implications of the newer computer will be examined after exploring the costs of replicating the present experimental approach.

The organization of the paper will be as follows: First, a brief description will be given of the present CAI system and its configuration in the LAUSD/ETS schools. Second, a short presentation will be made of the costing methodology that will be used in this study. Third, cost estimates for replicating the present CAI system will be made. Fourth, the cost feasibility of adopting this system of CAI for compensatory education will be evaluated as well as the cost implications of a more advanced system.

THE SYSTEM OF COMPUTER-ASSISTED INSTRUCTION

The purpose of this section is to provide a brief summary of the implementation of computer-assisted instruction in the ETS/LAUSD study. This description is of special importance, because each CAI approach and installation is associated with different resource costs and effects. The ETS/LAUSD experiment is based upon the use of a particular computer system and curriculum that have been utilized in a specific way. Therefore, it is important to provide some description of the system and its application. It is equally important to bear in mind that the evaluation of this particular CAI approach with respect to costs or educational effects can not necessarily be generalized to other CAI approaches. Rather, all of the results will be limited to the specific CAI application that is being evaluated.

The heart of the ETS/LAUSD instructional approach is the use of the A-16 computer for providing drill and practice instruction for the students. Students are seated at terminals which consist of a keyboard (reasonably similar to that of a typewriter) and a cathode ray tube (or CRT which is similar to a television screen). Each A-16 can be used to service up to 32 terminals, simultaneously. The A-16 contains curricula for all of the elementary grades for each of the three subject areas: mathematics, reading, and language arts. Each session lasts for ten minutes, although some students may be assigned to undertake more than one session per day.

Each student "signs-on" at his/her terminal, and begins the session where he or she had left-off in the previous session. A problem is displayed on the CRT, typically in a multiple-choice or in a "fill in the blank" format. For example, the student might be given a problem in arithmetic operations such as vertical addition or subtraction, and he or she must type in the solution. Or, the student might be asked to fill in the correct form of a verb in a sentence. If the answer is correct, an asterix is displayed on the CRT; if it is incorrect, the student is so-informed. In either case, a new problem is displayed. When a student achieves adequate proficiencies on a particular part of the curriculum -- as evidenced by a high enough proportion of correct answers -- the system provides problems at a higher level of difficulty of that type. The curriculum is not designed to introduce new material as much as it is to provide an opportunity to practice concepts that have already been taught.

There are two principal personnel who assist the students in working with the CAI system. A coordinator is responsible for the entire operation in a particular school including the scheduling of students; the provision of summaries of progress for each class to the classroom teachers (available from a printer that is attached to the A-16); the security and condition of the equipment (such as insuring that the equipment is working properly and calling maintenance personnel when necessary); and the overall supervision of the students in working at the terminals. The coordinator is assisted by a teaching aide who monitors the students and answers their questions or assists them when they seem to be having difficulties.

The LAUSD/ETS experiment was based upon using four experimental schools and two comparison ones that would not receive the CAI. Two of the four experimental schools were large enough that they could utilize an A-16 with a full complement of 32 terminals. The other two schools had smaller student populations, so they shared an A-16 through the use of telephone lines and special equipment (multiplexer and modems). Each of these schools had 16 terminals installed, so that the shared A-16 was also attached to a total of 32 terminals. The CAI rooms had to be modified to accomodate the special configuration of equipment as well as to assure security and an appropriate climate of temperature and humidity for maintaining the computer.

COSTING METHODOLOGY

The concept of costs typically tends to be confusing to evaluators. Often, the tendency is to review budgets to estimate the costs of a particular project. But the costs that one finds in a budget or accounting statement are often in error or are misleading for a number of reasons: First, budgets typically show estimated costs rather than actual ones. To the degree that there are discrepancies between the real costs and the estimated ones, budgetary costs will not be accurate. Second, budgetary costs often provide costs of resources that will be used over different time periods. For example, while salaries in a given year will cover the labor services during that period, a piece of equipment may be utilized for many years. Yet, the cost will be assigned only to the year in which the equipment was purchased, when it should be divided over the entire period of use on an annualized basis. Third, costs of contributed inputs are not included in budgets, confusing the question of what are the true costs of a project with the question of who paid the costs. Finally, some budgetary costs are distorted because they represent special purchases or transactions which do not reflect the true market values of the transactions.

A more appropriate method for estimating costs is to use the ingredients method.[3] This method is based upon the assumption that whenever resources that have alternative uses are allocated to a particular activity, those resources have a cost to society. The cost is equivalent to the value of the resources in their most productive application. The most typical way of estimating these costs is to use the market value of the resource. Further, in order to obtain annual or costs of an alternative, the costs of various ingredients that are utilized over more than one year are "annualized" in order to charge to each year only the costs for that period (rather than assigning the entire cost to the year of purchase). Since there are sources that can be used to evaluate the techniques of cost analysis within this framework, we will not discuss them in detail here.[4]

The following steps are necessary for estimating costs, using the ingredients approach.

1. List all of the ingredients or resources that are required for implementating the instruction.
2. Estimate the costs of each ingredient on the basis of actual costs or estimated market values.
3. Convert costs into the appropriate categories for analysis such as annualized costs, average costs, marginal costs, and so on.

In this particular case we wish to estimate the costs for replicating the ETS/LAUSD system of CAI in other educational settings, and we wish to evaluate costs under different organizational arrangements.

CAI Ingredients and Their Costs

Before enumerating the various ingredients of the CAI system and their costs, it is useful to mention the bases on which ingredients might be classified as well as the sources of the cost information. The classification of ingredients can be done in any way that is functional to the questions that will be raised. For example, one could classify ingredients under personnel, facilities, equipment, and miscellaneous categories. Or one could set out categories of ingredients that represent fixed investments as well as those that represent recurrent cost items. The main criteria are that all ingredients are accounted for in the classification approach and that the ultimate categories are useful for analytical purposes.

The derivation of cost information for the various ingredients will be done in a number of ways. Where budgetary and accounting information are appropriate, they will be used. Where such cost data are inappropriate or misleading, other methods of obtaining costs will be utilized. In all cases, the sources of the cost information will be specified as well as the methods of cost estimation. In this way, the reader can ascertain how the costs were derived, and it is also possible to modify the assumptions on cost estimation to determine the sensitivity of costs to different premises.

COST ESTIMATES

For purposes of cost estimation, the ingredients of the CAI approach will be divided into six categories: (1) Facilities and Equipment; (2) Training; (3) Personnel; (4) Curriculum Rental; (5) Maintenance; and (6) Miscellaneous Factors. Each of these will be evaluated, in turn, and they will be combined in analyzing the overall costs of CAI.

(1) Facilities and Equipment

Any CAI approach has the obvious requirement of the equipment needed as well as the facilities needed to provide CAI instruction. In the case of the Los Angeles experiment, the equipment for a school using a single A-16 computer, 32 terminals, and a printer is estimated at about $121,000. The separate breakdowns for each type of equipment are shown in Table 1. That table also presents the estimates of facility costs. These include the cost of construction of a normal instructional classroom as well as the renovations that must be made to accomodate the CAI.[5] Renovation costs include special carpentry work, protective devices, electrical work unique to the CAI installation, and air conditioning. The facilities costs are estimated to be about $68,500, and the total value of the equipment and facilities is assessed at almost $190,000 per school.

However, we are not concerned with the total costs of these ingredients as much as we are with their annualized costs. That is, a classroom is assumed to have a life of 25 years, so that only about 1/25 of the cost should be allocated to a particular annual period.[6] The renovations are assumed to have a life span of ten years, and the equipment is estimated

TABLE 1 -- Facilities and Equipment

Facilities:	
Cost of Construction of a CAI Room[1]	$ 50,000
Renovation Cost[2]	18,500
	$ 68,500
Equipment:[3]	
One A-16 Computer System	$ 68,120
Installation	3,000
32 Hazeltine Modular I terminals @ $1440/ea	46,080
Delivery @ $63/ea	2,016
One Hazeltine Thermal Printer	1,950
Delivery	23
	$ 121,189
TOTAL	$ 189,689

1. It was reported from the Educational Housing Branch in Los Angeles that to replace a room in which the CAI experiments are now housed in the present construction market will cost approximately $50,000 per room.

2. The renovation costs include counters, intrusion alarm, carpentry, paint, electrical, window grilling, air-conditioning and the labor involved.

3. These costs are derived directly from the CCC contract.

to have a life span of six years.[7] In each case we must use a standard approach to convert the overall costs into annualized ones, where the annualized cost represents the depreciation and interest costs foregone on the investment for each year. Clearly, the annualized cost will depend on three factors: (a) the overall investment cost; (b) the life of the facilities or equipment or the amortization period; and (c) the rate of interest on the investment that is foregone.[8]

Table 2 shows the annualized values of facilities and equipment costs with the specific assumptions about the amortization period and three different interest rates. Given a rate of interest on U.S. treasury bonds of about 10 percent at the present time, this seems to be a reasonable figure for calculating foregone interest on the investment. On that basis, the annualized cost of facilities is about $8524 and that of equipment is about $27,873. Thus, the estimated cost of facilities and equipment is about $36,397 per year.

(2) Training Costs

Training costs are composed of two types, the direct costs of training and the indirect costs. The direct costs are the most obvious ones, consisting of the salaries of instructors, costs of materials, and so on. The indirect costs refer to the value of the time of the trainees. In the case of the LAUSD project, the direct costs of training were included in the costs of equipment by CCC. However, the indirect ones had to be borne separately. According to the experience of CCC personnel, it is usually sufficient to provide workshops of a day and one-half for coordinators and half a day for teachers. The cost for each teacher and coordinator will vary according to experience and training and the salary levels in the particular school district. However, in Los Angeles it appears that salaries and fringe benefits average about $20,000 for a school year that is not more than 200

TABLE 2 -- Annualization of Facilities and Equipment Costs

Cost Categories:	Amortization Period (yrs)	Cost	Annualized Cost 0%	Annualized Cost 10%	Annualized Cost 15%
Facility					
Construction of a CAI room	25	$ 50,000	$ 2,000	$ 5,508	$ 7,750
Renovation	10	18,500	1,850	3,016	3,682
Facility Subtotal		$ 68,500	$ 3,850	$ 8,524	$11,432
Equipment[1]					
Equipment Subtotal	6	$121,189	$20,198	$27,873	$31,994
TOTAL			$24,048	$36,397	$43,426

[1] Refer to Table 1 for the details. The amortization periods for all computer related equipment are assumed to be 6 years.

TABLE 3 -- Annual Personnel Costs

Administration	$ 1,965
CAI Coordinator	22,500
Fringe Benefits on above @ 16.7%	4,086
Two teaching aides	5,220
Substitutes	780
TOTAL	$ 34,551

days. This suggests that a pay rate of about $100 a day is an appropriate basis for calculating costs of the time required by teachers and coordinators to obtain training. Given about 40 teachers to an elementary school, the indirect costs of teacher training are about $2000 for a half-day workshop and about $150 for a 1.5 day workshop for the coordinator. Thus, the total estimated indirect costs of training are about $2150.

One question that arises is how this figure translates into an annualized cost. It is unlikely that training costs of this magnitude would be required for each year, since the carryover of trained teachers and coordinators from year-to-year would be rather high. Yet, any turnover of teachers will require some training to take place each year, even if it is merely the coordinator taking the teacher away from his or her classroom duties for half a day for instruction. For example, with a turnover rate of ten percent a year, about four new teachers would have to be trained each year at a cost of about $200. In fact, after the first year this would be the only cost of training as well as the interest foregone on investments for training in previous years. If we use those two components to estimate costs, the total indirect training costs would be ten percent of the previous investment in training per year plus the costs of training new teachers. On the average, ten percent of the training investment over a six year period would be about $250 and the indirect cost of training four new teachers a year would be about $200 for a total of $450 a year. Whatever the assumptions are about the costs of this component, the overall cost implications are so small that they will have little impact on the total cost calculations.

(3) Personnel

Personnel ingredients for the CAI demonstration include administrative resources, the CAI coordinator, two teaching aides, and substitutes to cover the absences of the coordinator. These are shown in Table 3. The function of the administrative personnel is to negotiate the contracts with the companies that maintain the equipment, to arrange payments, and to provide general financial and logistical administration of the project. The annual personnel costs for this function were estimated at $1965 on the basis of previous experience of the Los Angeles schools with these types of projects.

The CAI coordinator is responsible for the overall functioning of the CAI instruction including the scheduling and coordination of the instruction, reports to teachers on student progress, and the monitoring of the functioning of the equipment and its maintenance. Especially important is the latter function, since equipment failures will result in the loss of instructional sessions. Accordingly, the coordinator must be aware of problems and the methods of getting them alleviated by the appropriate maintenance personnel. Further, the coordinator must work closely with classroom teachers to integrate the drill and practice sessions of CAI with classroom work.

In the LAUSD case, the coordinators were so carefully chosen and so well-trained that they needed little administrative supervision from the school principal or other school administrative personnel. Whether this high level of initiative and independence could be maintained in a replication is problematic. However, based upon the success of coordinator autonomy in LAUSD, we have not indicated any supervision in the cost estimates. The cost of the coordinators can be determined directly by calculating salaries and fringe benefits. The salary component was estimated at $22,500 and the fringe benefits for that portion of the administrative costs and the coordinator were $4086. Fringe benefits do not apply to the other personnel categories because of their part-time nature.

Teaching aides monitor the performance of students and assist them in understanding the CAI problems and in solving them. Essentially, they wander among the students, looking for situations in which assistance or supervision is needed. Their rate of pay in 1977-78 was $4.35 an hour, and it takes two teaching aides working about 600 hours each school year to assist in a CAI room with 32 terminals. This particular arrangement has been considered highly satisfactory by the Los Angeles coordinators. The total cost per CAI room of the two aides is about $5220 a year.

The final personnel cost is related to the need for substitute teachers to undertake the coordination functions if the regular coordinator is ill. Under the Los Angeles arrangements, a teacher or coordinator can receive up to 12 days a year in paid sick leave. Therefore, provision for up to 12 days of substitute teaching at about $65 a day would cost about $780 per year. Based on these amounts, the personnel costs per year (for 1977-78) totaled about $34,551.

(4) Curriculum Rental

The curricula that are used for the CAI approach are rented from CCC, the company that provided the A-16 system. The rental covers the cost of using the three sets of subject curricula in mathematics, reading, and language arts. The cost of the rental is set at $204 a year for each of the 32 terminals in a CAI room for an annual total of $6528.

(5) Maintenance

The provision for maintenance of the equipment is arranged through contracts with firms that specialize in such care. While some of the maintenance is routine and periodic, a major requirement is services of an emergency nature to repair malfunctions. The annual cost of maintaining the A-16 computer is $6120 a year; each of the 32 terminals has a maintenance cost of $300 a year, or $9600 for all terminals in a CAI room; and the thermal printer has a maintenance cost of $360 a year. The total cost of maintenance is about $16,080 a year.

(6) Miscellaneous Factors

Miscellaneous cost factors include insurance, supplies, and the costs of energy and routine maintenance of the classroom. The appropriate insurance costs are those that are incurred by virtue of the existence of the CAI approach. These would include the additional insurance costs for theft, fire, and liability attributible to the CAI facility and equipment. Of these components, it appears that liability insurance is largely unaffected, and the impact on fire insurance costs is not readily ascertainable. However, the additional theft insurance for the equipment was estimated by the Los Angeles school authorities at about $3,000 a year for the computer, 32 terminals, and the printer. The use of only the theft component may understate slightly the true insurance costs, by omitting the fire component. However, the overall omission is likely to have a relatively small effect on total costs, since insurance represents a very small relative cost item.

Supplies, energy, and routine maintenance of the classroom contain many items. Supplies include the typical pencils, paper, books, paper for the printer, and so on. Energy and telephone costs and facility maintenace refer to the telephone in each classroom that is necessary for rapid access to maintenance personnel and CCC--in case of breakdowns; normal heating, lighting, and power for the equipment; and routine cleaning and maintenance of the classroom. Taken together, these are estimated at about $3,000 per year. Again, even substantial changes in this amount (for example 50%) would have little effect on overall costs per student session because of the relatively small magnitude of costs for the category. (Each classroom is capable of providing a daily session on an annual basis for over 700 students so an error of $1500 is only about $2.00 per session.)

Summary of Annualized Costs

The annualized costs in 1977-78 for a 32 terminal classroom utilizing the CCC A-16 system can be summarized in the following tabulation.

Facilities and Equipment	$ 36,397
Personnel	34,551
Training	450
Curriculum Rental	6,528
Maintenance	16,080
Miscellaneous	6,000
Total	$100,006

Rounding off this estimate, it appears that it costs about $100,000 a year to provide a classroom, personnel, equipment, and so on for servicing 32 terminals with this particular approach to CAI.

Average Cost Per Session

Given this total, it is important to know the cost per session on an annual basis for each student. That is, what is the cost for providing one daily session of ten minutes of drill and practice for a full school year to each student? The reason that this particular cost figure is important is that it would enable us to ascertain the cost-feasibility of this approach to CAI as a method of providing compensatory education to disadvantaged youngsters, by comparing the amount per session with the average amount of compensatory funds provided by the federal government under Title I of the Elementary and Secondary Education Act of 1965.

Clearly, the cost per session depends on the number of daily sessions that can be provided by the CAI system on an annual basis. This depends not only on the length of the session, but also on the organizational capacity and time required to process each group of student users. That is, there must be time between the end of one ten minute session and the beginning of the next for one group of students to sign off the system and return to class, while a new group arrives, is seated, and signs in. Finally, the number of sessions will also depend upon the overall reliability of the equipment and its operability during school hours.

In theory, the system could be used for up to six and one half hours a day during regular school hours, if sessions began at 8:30 and proceeded to 3:00 P.M. with no interruptions for lunch. In fact, this would be difficult to do organizationally, since time is needed at the beginning and/or end of the day to accomplish record-keeping and other instructional tasks associated with CAI. Further, it would be difficult to coordinate classes around the lunch period, and a "relief" coordinator would be needed during that period. With respect to the number of sessions per hour, even five sessions of ten minutes each provide only about two minute transition periods. Accordingly, there are clear limits on the numbers of sessions that can be accomodated. Based upon the actual records for the LAUSD system, it appeared that the range varied from 21 sessions to 25 sessions per day, with a median of about 23 sessions. On the basis of these experiences, we can estimate the cost per daily session per student for a school year.

Number of Sessions Per Day		Annual Cost Per Daily Session
Per Terminal	For 32 Terminals	
21	672	$ 148.80
23	736	135.90
25	800	125.00

Depending on the number of sessions per day for each terminal, a configuration using the A-16 and 32 terminals in a single classroom can accomodate from 672 to 800 sessions a day. Assuming that the most probable estimate is the median of 23 sessions a day per terminal, 736 sessions can be provided. By dividing the number of sessions by the $100,000 estimated annual total cost for this CAI configuration, it appears that the annual costs for a daily session of ten minutes could vary from about $125 to almost $150 per year for one daily session of CAI. The estimate for 23 sessions a day at $136 is probably the most reasonable one.

Cost Estimate for the Shared System

Before comparing that cost with the level of funding available for compensatory education, it is important to estimate the annual cost per daily session when two schools share an A-16 system. Clearly, this situation presents itself when there is not an adequate student enrollment base in a particular school to accomodate some 700 or so daily sessions. It could also be evident in situations where only a particular grade level or levels utilized the CAI. Of course by providing multiple daily sessions, (e.g. two sessions a day), an A-16 could be utilized to full capacity by even 350 - 400 students. However in the Los Angeles situation, the design of the CAI experiment meant that in two participating schools there were not adequate students assigned to CAI to fully utilize a 32 terminal system in each school. This situation provides us with the opportunity to ascertain the costs of a shared CAI computer.

The basic configuration for the shared system was that the A-16 computer and 16 terminals were placed in one school, and the other 16 terminals were placed in a "sister" school. The terminals were connected to the first school through a leased telephone line, and additional equipment was required in order to operate the sharing arrangement. Table 4 shows the additional costs incurred for a shared A-16 system. With the shared arrangement, two classrooms must be utilized for the terminals rather than one classroom. Based upon the costs for a classroom and required renovations that were presented in Table 2 and replicated in Table 4, the total cost of additional facilities for the shared arrangement would be $68,500 which would be about $8,524 on an annualized basis.

The additional equipment (two modems and two multiplexers) and their installation have a cost of almost $12,500 which translates into an annualized cost of about $2,866. Taken together the additional outlay for the shared facilities and equipment is almost $81,000 which translates into an annualized cost (using a 10 percent interest rate on the (undepreciated portion) of $11,390. With respect to personnel for the shared arrangement, we assume that the administrative costs for making financial arrangements and monitoring contracts is roughly equivalent to the single school approach. However, an

TABLE 4 -- Additional Costs Incurred for Shared A-16 System

Cost Categories:	Amortization Period (yrs)	Cost	Annualized Cost 10%
Facility			
Construction of a CAI room	25	$ 50,000	$ 5,508
Renovation	10	18,500	3,016
SUBTOTAL		$ 68,500	$ 8,524
Equipment			
Two Modems	6	$ 4,710	$
Two Multiplexers	6	7,550	
Installation	6	200	
		12,460	2,866
TOTAL		$ 80,960	$ 11,390
Personnel			
One Coordinator			22,500
Fringe Benefits on above @16.7%			3,758
Substitutes			390
SUBTOTAL			$ 26,648
Maintenance			
Printer			$ 360
Miscellaneous			$ 3,000
GRAND TOTAL		$ 80,960	$ 41,398

additional coordinator is needed for the classroom in the shared configuration, and additional provision for substitutes is necessary. These are estimated to cost about $26,648 per year. The training cost for the additional coordinator is so small that it is inconsequential (about $150 for the day and one half of salary) and will not be included in the total.

Additional costs of maintenance seem to affect only the additional printer at $360 a year and the modems and multiplexers are maintained on the basic CCC contract, so their costs can not be easily broken out. Miscellaneous costs include the telephone line between schools, routine maintenance of the facilities, lighting, heating, electric power, and supplies. These are estimated at about $3000 per year, and insurance costs are not affected by distributing the terminals between the two schools.

When these additional costs of the shared arrangements are totaled, about $41,400 is added to the total cost in comparison with the single classroom, 32 terminal, A-16 approach. Again, assuming 23 daily sessions per terminal and a total cost of about $141,000 per year for the shared system, the annual cost per daily session of CAI instruction is about $192. In other words, the shared system increases the cost per session by about 40 percent or $56.

COST FEASIBILITY

Are these costs high or low? Clearly that depends on what the costs are buying in terms of educational services and effectiveness in relation to what spending those funds on alternatives might produce. Such cost effectiveness comparisons are absolutely essential in using cost information to ascertain whether a particular educational technology or other instructional approach is a good investment. However, we lack both the cost of other alternatives and effectiveness data on CAI versus other alternatives for this paper. Some of those data will be forthcoming at the completion of the CAI experiment and can be drawn upon for cost-effectiveness comparisons at that time.

The purpose of cost feasibility analysis is much more modest. It simply asks if the costs of the instructional approach can be accomodated within the limits of the budget assigned for such purposes. In order to answer that question, we will wish to compare the costs of CAI with the level of funding provided for compensatory education by Title I of the Elementary and Secondary Education Act of 1965. That is, presumably the CAI system that is being evaluated is addressed primarily to drill and practice for remediation. Accordingly, this would seem to be the most relevant framework for a cost - feasibility analysis.

In fiscal year 1977, Title I had appropriations of about $2 billion for about 5 million youngsters. This means that on the average about $400 was provided for each of the students covered by the program. Clearly, not all of this was allocated to classroom instruction. Some was expended on administration, health and diagnostic services, nutrition, and so on. However, we will assume that about $400 per pupil represents an upper limit for compensatory education in the classroom. Using this as a basis for cost feasibility, $400 would cover about three daily sessions of CAI at $136 per session with 32 terminals to a classroom or two sessions at $192 under the shared arrangement. This means that all three curricula could be provided under the lower cost configuration or two could be provided under the higher cost one. It also means that two curricula, for example reading and mathematics, could be provided under the lower cost option, while allowing the remaining $128 per student to be used for other purposes. On this basis, one would conclude that the CAI appraoch that has been evaluated meets a general cost-feasibility test. That is, it is feasible to consider this approach within the constraints of existing provisions for compensatory education.

COSTS OF A MORE ADVANCED SYSTEM

One of the major questions that arises in evaluating the costs of a changing technology is the direction and magnitude of future costs based upon more advanced approaches. This is particularly important in any strategy based upon computers, since the technology of mini-computers and memory devices has been developing at a rapid pace with drastic reductions in the cost of any given capability. Clearly, the longer run situation would suggest that at least the cost of equipment with a given performance would decline, and it is important to ascertain the impact of these potential equipment cost declines on the overall costs of CAI instruction.

However, before examining some evidence on this question, it is important to point out a phenomenon which is typically overlooked in predicting cost changes of technological innovation. The annualized costs of all the computer equipment including the terminals represented only about 28 percent of total annualized costs,as evidenced by comparing the costs of $27,873 in Table 2 with the total costs of $100,000 for a 32 terminal classroom. This means that even a rather drastic reduction in the 28 percent of the cost accounted for by equipment will amount to a much smaller reduction in the total cost. For example, if the cost of equipment declined by one third, total costs would decline by less than ten percent. At the same time, the costs of personnel, maintenance, construction and other personnel intensive categories are rising rapidly, at least offsetting partially the potential declines in the cost of computer hardware. Accordingly, it is important to recognize that there will be inherent limits to cost reduction for CAI, even with rapid technological improvements in hardware.

In the particular case of the A-16 system, we were fortunate in that CCC had developed a more advanced CAI approach during the implementation phase of the LAUSD experiment. The more advanced computer is the CCC-17 which can drive some 96 terminals rather than the 32 terminals to which the A-16 is limited. CCC also claims that the 17 is more flexible and productive than the A-16 for a number of reasons. First, it uses special terminals provided by CCC which permit more flexible design and format of curricula as well as a wider variety of interactive, feedback responses between the pupil and the computer. Second, the central processing unit has greater capacity for storing additional curricula and can process curricula of a wider variety than the A-16. For these reasons the CCC-17 may also be more effective for each session that the A-16, although that is ultimately an empirical issue rather than a theoretical one. CCC has provided the CCC-17 for one classroom for the final year of the LAUSD/ETS experiment, so some empirical data should be forthcoming on this issue.

However, the purpose of this investigation is to ascertain the cost per session of the newer technology. Since the CCC-17 represents a larger system capable of supporting 96 terminals, we will estimate the costs of using a single CCC-17 for providing CAI to three classrooms of 32 terminals. This will enable us to ultimately compare the costs of the CCC-17 for 96 terminals with that of the A-16 on a 32 terminal classroom basis.

Table 5 shows the estimated total and annualized costs of both the facilities and equipment for the CCC-17 configuration. The cost of the

TABLE 5 -- Annualized Cost for Three (3) Schools Sharing the CCC-17 System

Cost Categories:	Amortization Period (Yrs)	Cost	Annualized Cost 0%	Annualized Cost 10%	Annualized Cost 15%
Facilities					
Construction of CAI Room	25	$ 150,000	$ 6,000	$ 16,500	$ 23,250
Renovations	10	55,000	5,550	9,047	11,045
SUBTOTAL		$ 205,500	$ 11,550	$ 25,547	$ 34,295
Equipment					
Computer-Related Equipment (includes terminals)	6	$ 314,814			
Installation	6.	13,800			
SUBTOTAL		$ 328,614	$ 54,769	$ 75,581	$ 86,754
TOTAL FACILITIES AND EQUIPMENT		$534,114	$ 66,319	$101,128	$121,049

facilities component is identical to that shown in Table 2 except that it is based upon three classrooms rather than one classroom. (Of course we will evaluate the costs per session based upon the larger number of terminals serviced by the CCC-17 to make the cost estimates comparable on a student session basis.) The equipment costs include the CCC-17 system, 96 terminals, a cluster controller for every 32 terminals which provides power to the terminals and routes information between the computer and terminals, a printer for each school, modems for remote schools, and tables for each CAI room. All of the cost figures are taken from published documents furnished by the marketing office of CCC (dated April 17, 1978). Total facilities and equipment costs are $534,114 or about $101,128 in annualized costs when the interest rate on the undepreciated investment is ten percent.

Personnel costs and the indirect costs of training were calculated in the same manner for the CCC-17 configuration as for the A-16, except that they are shown for three classrooms. These and other costs are reflected in Table 6. Curriculum rental was estimated by CCC at $20,857 and maintenance at $42,072. The miscellaneous costs are also similar to those calculated for the A-16. The total of all of these components is $181,931 and when the annualized costs of the equipment and facilities of $101,128 are added, the total annualized cost of the CCC-17 is estimated to be $287,059. In order to find the average cost per session, we need only divide this annual cost by the number of daily session provided on an annual basis. This is shown under different assumptions about

TABLE 6 -- Annual Costs of Personnel, Training, Curriculum Rental, Maintenance and Miscellaneous Components of CCC-17

Personnel	
Administration	$ 5,895
Coordinators	67,500
Fringe Benefits on above @16.7%	12,257
T.A.'s	15,660
Substitutes	2,340
SUBTOTAL	$ 103,652
Training (indirect costs)	$ 1,350
Curriculum Rental	20,857
Maintenance	42,072
Miscellaneous	18,000
TOTAL	$ 185,931

the number of daily sessions provided:

Number of Sessions Per Day		Annual Cost Per Daily Session
Per Terminal	Per 96 Terminals	
21	2016	$ 142.30
23	2208	130.00
25	2400	119.60

Based upon the median number of 23 daily sessions, the average cost per session for the CCC-17 is estimated to be about $130 in comparison with about $136 for the A-16.[9]

This suggests that the CCC-17 has a cost that is about five percent lower per CAI session than the A-16. This represents a rather small difference, especially since it assumes that the CCC-17 is utilized to capacity. One of the advantages of the smaller scale of the A-16 is that it provides somewhat more flexibility. Since it can be utilized in multiples of 32 terminals, there is likely to be less of a problem in underutilization than a system that must be implemented in multiples of 96 terminals. Because of the high fixed costs of these types of systems, underutilization hardly reduces total costs at all. This means that one must divide relatively irreducible total costs over fewer sessions, with a marked rise in cost per session. For that reason, the five percent reduction in cost per session under assumptions of full utilization would deteriorate rather quickly if the CCC-17 could not be fully utilized at a scale of 96 terminals.

One other point that ought to be emphasized is that of the total annual cost of $287,000 for the CCC-17, only about $76,000 is accounted for by the cost of the computer hardware. This means that almost three quarters of the cost is allocable to factors that are not ostensibly affected by improvements in computer technology, thus limiting the cost savings obtainable by technological advances in the CAI system. In fact, as a general rule, virtually all technologically-based instructional systems will show only about one quarter to one third of the costs are associated with their "hardware." This means that drastic reductions in the costs of such hardware may have only nominal effects on overall costs of the instructional strategy. Further, to the degree that the decrease in even those costs is associated with a larger scale of operation, even these cost reductions may not be realized unless the system can be utilized to full capacity.

It should be noted that according to CCC, the CCC-17 is educationally superior to the A-16. Clearly, the cost per session is not as important as the cost per unit of educational effectiveness. Thus, even if the costs of the CCC-17 are comparable to those of the A-16, a superior level of effectiveness may still make it a better investment. However, without data on the relative effectiveness of the two systems, it is impossible to evaluate this claim.

SUMMARY

The purpose of this paper was to estimate both the costs and cost - feasibility of utilizing a particular CAI approach for compensatory educational purposes. The particular approach that was chosen is the CCC A-16. and its implementation for a four year experiment on the effectiveness of CAI that had been established in the Los Angeles Unified School District.

Based upon the ingredients approach to cost-analysis, it was found that up to three sessions of drill and practice of ten minutes duration could be provided for each disadvantaged child at the present level of Title I expenditures. This means that three different subjects could be provided or that multiple sessions in one or two subjects could be offered for each child. As such, it appears that the instructional strategy is cost - feasible within present provisions for compensatory education. Utilizing the A-16 between schools would increase costs rather substantially, but two sessions of CAI would still be feasible within present compensatory educational allocations.

Costs were also estimated for the more advanced CCC-17 computer system, and somewhat surprisingly the costs were in the same range as those of the A-16. In part, this finding reflects the very heavy "software" components of CAI approaches, and, in part, it may reflect the possibility that the CCC-17 is more effective than the A-16 (even though the costs are quite similar). It is clear that a more exhaustive analysis of the merits of different CAI approaches as well as a comparison between them and other instructional strategies will require effectiveness data as well as cost estimates. Some of these should be forthcoming from the ETS/LAUSD experiment, and it is hoped that a cost-effectiveness comparison can be made at some future date.

FOOTNOTES

1. The best studies in this area are Jamison et al. 1976 and 1970 with respect to CAI. However, cost-effectiveness analyses of other technologies can be found in Instructional Science 1975. See Carnoy and Levin 1975 for a critique of the methodologies of these studies.

2. These studies will be forthcoming in 1980 by Paul Holland, Dean Jamison, and Marge Ragosta of Educational Testing Service.

3. Virtually all of the issues discussed here are reviewed methodologically in Levin 1975. The best application of costing methodologies to instructional technologies is Jamison et al., 1978.

4. Ibid. This paper will not include student time as a resource, since it is difficult to place a value on this dimension. However, alternative instructional strategies with mostly different demands on student time should take this component into account.

5. As school enrollments decline, it is common for some observers to question whether any cost should be attached to newly available classrooms that are no longer needed to service regular enrollments. However, such facilities are not costless as long as they have alternative uses. In fact, there are a large number of alternative uses as evidenced by the expansion of special education programs, rental of rooms to other public agencies, or the closing of schools and their rental or sale.

6. The useful life of school facilities is taken from estimates by LAUSD administrators.

7. CCC staff gave us a figure of 6-10 years depending on level of utilization and assessments of technical obsolenscence. We have used the six year figure because of the very intense level of utilization of the equipment. However, extending the estimated life to ten years would have the effect of reducing the overall instructional costs by no more than 2-3 percent.

8. See Levin 1975 and Jamison et al., 1978.

9. Jamison et. al., 1970 suggests that at that time a cost of $50 per session was attainable on an earlier CCC system. That estimate seems overly optimistic; even when adjusted for inflation it is about half of our estimates. Most of the difference appears to arise from the fact that coordinators were not used in the configuration that they describe as well as the assumption that the utilization rate would be 25 sessions daily. They do not mention the number of minutes per session. Early "drill and practice" curricula utilized seven minute sessions, and they may be assuming these shorter sessions.

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B.

TOWARDS A META COST-EFFECTIVENESS ANALYSIS OF EDUCATIONAL INTERVENTIONS

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TOWARDS A META COST-EFFECTIVENESS ANALYSIS OF EDUCATIONAL INTERVENTIONS

I. INTRODUCTION

This report has its origin in earlier work that was done on the cost analysis of a particular educational intervention using computer-assisted instruction (CAI) to improve the educational performance of youngsters who were defined as educational disadvantaged. (Levin and Woo 1981) Under the sponsorship of the National Institute of Education (NIE), the Los Angeles Unified School District (LAUSD) and the Educational Testing Service (ETS) collaborated in a unique experiment to test the effectiveness of a specific application of CAI in raising the test scores of students in mathematics, reading and language arts. The experiment was unique in that it was designed to examine the effectiveness of CAI along many dimensions including differences in amount of daily instruction, in number of years of instruction, and in subject area. The fact that the experiment was carried out over a four year period, from 1976-1980, meant that the cumulative effects of CAI could also be examined.

One of the concerns of the sponsoring agencies and educational policy-makers more generally is the question: Is CAI more effective in raising academic performance of disadvantaged youngsters, relative to its cost, than other educational interventions? Put more succinctly, is CAI a more cost-effective strategy than other educational alternatives for improving the educational proficiencies of the disadvantaged? Since the purpose of the ETS/LAUSD experiment was to examine the effectiveness of CAI, that particular information was likely to derive from the evaluation.

In order to provide the pertinent data on costs, a special study was initiated to ascertain the cost of replicating the specific CAI approach that was taken in the experiment. Using the ingredients or resource method of estimating costs, it was found that a daily ten minute session could be provided over the school year for about $135 per student in additional costs in 1978. Given the funding available in 1978 under Title I of the Elementary and Secondary Education Act of 1965, about $400 per student, as many as three sessions could be provided per child on different subjects or a single subject. Or, more realistically, two sessions could be provided while still leaving about $130 available for other Title I services.

In summary, both estimates of costs and effects were derived for the experiment. But, clearly these data are not adequate for a comparative study of cost-effectiveness of different educational interventions without similar information on other educational alternatives. That is, knowing both the cost and effectiveness of different amounts of CAI in different subjects is not adequate in itself for judging the relative cost-effectiveness of CAI. Rather, we also need similar types of data for the alternatives to CAI. But, given the inability to initiate costly, multi-year experiments for the educational interventions, such data cannot be derived in the same careful and painstaking way that they were derived for the CAI.

The purpose of this study is to develop an approach for comparing the cost-effectiveness of CAI with other approaches in the absence of such experimental data. The approach builds on the meta-analysis strategies developed originally by Gene Glass and Richard Light and their colleagues and refined by Glass, McGaw and Smith (1981). The idea behind meta-analysis is that we can learn more about any particular phenomenon by drawing upon all of the evaluations of that phenomenon than by relying on any single one. Each evaluation contains potential information that others may not have, since each is based upon scope and treatment conditions that are likely to differ from other studies. For example, different studies will analyze different intensities and versions of a single treatment and will apply them to different populations. A generalization about the phenomenon should draw upon this wide and richer range of conditions than any single study could encompass.

The evaluation approach that tries to generalize about a phenomenon from judicious analysis of all of the studies on that phenomenon is known as a meta-analysis. This does not mean that all studies are weighted equally in the analysis. Some may be discarded because they do not meet even minimal criteria for acceptability on the basis of such factors as poor design, inadequate measurement, and so on. Of course, these issues often are matters of degree. That is, there is no "perfect" evaluation, given the complexity of the world in which social phenomena take place. But, some evaluations are better or more appropriate than others, given the particular question of interest. Meta-analysis represents an attempt to assemble a large range of appropriate studies and draw generalizations by a judicious assessment of them to see what type of pattern seems to be evident.

Although the focus of this study is on the development of a meta-analysis for cost-effectiveness evaluation, the meta-analysis of effectiveness, itself, will not be a focus. Under separate arrangements, Gene Glass of the University of Colorado has been working on a parallel study of meta-evaluations of the effectiveness of CAI, reducing class size, teacher retraining and tutoring interventions. All of these represent potential alternatives for attempting to improve the education of disadvantaged youngsters. This particular study will focus, instead, on developing meta-evaluations of the costs of these interventions and combining them with the Glass estimates of effectiveness into cost-effectiveness measures that can be used to assess the available alternatives that might be considered by decision-makers.

This report will proceed in the following way. First, we will discuss the methodology for estimating costs and its applicability to a meta-analysis approach. Specifically, we will be concerned with the problems that arise in this type of application. Second, we will review cost models for the four interventions that are being examined by Glass: (1) CAI; (2) reduction in class size; (3) teacher retraining; and (4) tutoring. In doing this, we will focus on the concepts as they apply to each type of intervention rather than the final cost estimates. Finally, we will discuss those issues that arise in bringing these together in a policy framework with the effectiveness estimates to create a meta-analysis of cost-effectiveness. The reader of this report should be warned that this document will be devoted primarily to conceptual issues, although some details on the cost models will be provided. However, the actual estimates of costs and cost-effectiveness will be the subject of a future paper rather than of this report.

II. DISCUSSION OF COST METHODOLOGY

The appropriate cost methodology for addressing this type of problem is known as the ingredients or resource approach. (Levin 1976; Levin 1981) This approach is based upon two essential steps. First, an inventory is made of the ingredients or resources that are required to replicate any particular alternative, for example, an educational intervention. Second, the resources or ingredients that are required are given a cost which is based upon the sacrifice or cost to society of using the resources for the intervention rather than for the best alternative use. A third step that is sometimes taken is to distribute the costs among those entities bearing them such as different levels of government, volunteers, and other private sources. Although these steps are straightforward in principle, they are rarely straightforward in practice for a variety of reasons. The most important of these are that ingredients for replicating an intervention are not always obvious or provided in any systematic way for the analyst, and costs are often found to be problematic or elusive. Worst of all, standard accounting approaches and budgeting techniques used in the educational sector will not provide an accurate picture of either ingredients or costs. Accordingly, a discussion of the principles is in order before proceeding to their application to the present case.

The basic notion behind the ingredients method of costing is that all resources required for replicating an intervention must be accounted for, and the proper value for using those resources for that intervention rather than an alternative use must be established. In this way, it is possible to establish a cost value that represents the "sacrifice" in terms of value of resources that society gives up to make the intervention. Such an estimate provides a consistent picture among alternatives on the nature and value of costs as well as an appropriate conceptual framework with regard to the economics of costs.

Identifying Ingredients

The process of identifying the ingredients for any particular alternative begins by asking the question, what resources are required to replicate a specific intervention that produced the effect that will be estimated. That is, the effectiveness of any particular intervention is based upon a number of ingredients that are brought together and organized in such a way to produce that effect. These ingredients include personnel, facilities, and materials. Since education tends to be labor-intensive, a substantial aspect will be personnel costs. Here we are concerned not only with the amounts of personnel, but also their qualities or characteristics.

Some of the ingredients are always obvious, and some are not. For example, the principal personnel who are involved in the intervention and the materials and equipment that are used are usually readily evident. Less obvious are administrative resources and facilities, when such provisions are shared with other programs or functions. However, there are various ways of estimating the portion of shared resources that should be linked to any particular activity. Finally, there are "hidden" ingredients, those that are not apparent. For example, in experimental interventions the experimenter and his or her staff are often expected to observe the experiment. But, what if the presence of the experimenter and staff serve to make all of the other personnel more highly motivated and attentive than they would be in the absence of such distinguished observers. In such a case, the personnel associated with the research function are indeed required to replicate the intervention as it is being considered, and its measured effectiveness is due, in part, to these "hidden" ingredients.

Using our definition of ingredients as all of those resources that produce the observed effect or result, all of these ingredients must be considered in setting out the overall resource requirements. Replicating the intervention without these "hidden" ingredients is likely to produce a different effect. Even if we consider that the effect of having experimenters around is unintended or a hawthorne effect and would not be replicated in other settings, the specific effects that we will be measuring will be based upon all of the ingredients including the influence of the experimenters. In fact, we will suggest below that the teacher retraining interventions seem to be highly susceptible to the influence of having nationally renowned researchers as observers.

Finally, even ingredients that are used in the intervention but provided for through contributions or voluntary personnel are identified. The fact that any particular ingredient is paid for by one constituency rather than another is not a reason for omitting it from the specification of ingredients.

The issue of who pays for what portions of an intervention is an important one that requires subsequent analysis, but no ingredient should be omitted from the analysis because it is "free" to the sponsor of the intervention. All ingredients or resources represent a cost to someone. At first we must concern ourselves only with identifying the ingredients and their costs, and later we can examine who might pay for them.

Costing the Ingredients

After identifying the ingredients, it is necessary to determine their costs. Although an accurate cost for many ingredients will be found in budget statements, many costs cannot be ascertained in that way. If it can be assumed that personnel are receiving the salaries and other benefits that they would obtain in the general market for their services, such information can be used to place a cost on these inputs. In some cases, costs will not be found in the budgets, and in other cases the costs will be incorrect. For example, volunteers, contributed facilities, or facilities that have been paid for previously will not be evident on any budget. Yet, because such ingredients have alternative uses that have value, there is a cost to using them for the intervention. That cost can be ascertained by determining what similar types of ingredients would cost if they had to be purchased.

Budgetary distortions occur when expenditures are based upon special arrangements of a non-market nature or when the accounting principles utilized do not reflect the actual use pattern of the resource. In the first case, one government such as a municipality may make a special and favorable arrangement with another government such as a school district to provide a surplus facility at a bargain price. The true cost or value is the amount that that facility would fetch in a lease or rental in the general market. In this situation, the bargain rate would understate the true cost or value of the facility. The most common distortion in budgetary costs relative to true costs is reflected in the situation where capital improvements are charged to the budget in a single year even though they have a life of many years. School districts and other units of government typically pay for equipment and the refurbishing of facilities in the year that such improvements were acquired. Yet, equipment and improvement of facilities have a life of many years, and the appropriate cost in any one year is to charge for only their depreciation and a rate of interest on the remaining investment.

The principles of estimating costs are partially based upon using market values and partially based on using "shadow" prices, the appropriate value for a resource if it were traded in a perfect market. In order to ascertain how these principles are applied, it is necessary to know both economic and accounting concepts. The economic framework provides a basis for ascertaining how to determine the cost of an ingredient, while the accounting framework sets out an operational principle for making the cost estimate. Economics without knowledge of cost accounting provides too abstract an approach for obtaining concrete cost estimates; and accounting without the conceptual framework provided by economics provides too applied a technique with all of the dangers of missing ingredients that are not found in budgetary or accounting documents.

Once the ingredients are identified and their costs determined, it is possible to determine the cost of each intervention. For each intervention a list of ingredients and appropriate costs is compiled. The total costs of each intervention can be divided by the number of students served or the number of service units provided to give a cost per unit. Or alternatively a cost per student can be compared with a measure of educational effectiveness for a specified population for all interventions to obtain cost-effectiveness measures among alternatives.

One additional step that is often taken is to ascertain the distribution of the cost burden among interventions. Consider that for some interventions the school district must pay all of the costs, while for other interventions it is possible to obtain contributed facilities and volunteers. In the latter case, some of the costs are borne by those who are volunteering or providing the facilities. In that case, the cost might be less to the school district for the latter intervention, even if its total costs to all of the payors is greater than in the first intervention. Obviously, the cost to the decision-maker will weigh heavily in his or her choice, regardless of the total costs of the intervention. Accordingly, a distributional analysis of cost burden is carried out to determine the costs to different constituencies of each intervention.

Meta-Analysis of Costs

A meta-analysis of costs begins with two major challenges. The first is characterized by the normal hazards of meta-analysis. Such hazards include the attempt to combine the results of a large and diverse set of studies carried out on different populations with different designs and objectives. But, in addition to these challenges, there is the additional one reflected by the fact that virtually all evaluations of educational interventions lack any cost perspective. In the meta-evaluations of educational interventions, at least, all of the studies will focus on a relatively common criterion of outcome. But, there is no comparable concern for estimating costs. The result is that such information is lacking in its most rudimentary form.

To begin with, most such studies include no discussion of costs or cost factors. Even worse, few have any systematic and reasonably complete description of the intervention and the ingredients that are required. This tends to be a deficiency of many evaluations in education. That is, the treatment is described in an idealized form, with little attention to the actual treatment that was received by students and with no serious attempt to describe carefully the ingredients that were used. The most severe shortcoming of evaluations of educational interventions from the perspective of doing cost analysis is this dearth of relevant information. That is, somehow through the scrutiny of a number of similar types of intervention studies and background reading on the intervention, the cost analyst must construct a reasonable cost model consisting of the ingredients required for the intervention and the probable costs of the ingredients. To a large degree this exercise can be only minimally informed by any specific study.

A related problem is the one that was mentioned above. Hidden ingredients represent a real possibility in a situation in which there is no systematic attempt to provide information on the treatment and ingredients as a central part of each study being reviewed in the meta-analysis. Not only is the cost reconstruction susceptible to omitting hidden ingredients, but it must also risk guessing which ingredients are necessary for replication. In the teacher retraining studies, observers from projects that were directed by nationally-known researchers in teacher effectiveness were used to determine if the teachers were utilizing their training. In the evaluations of these interventions, such observers are treated as part of the data-gathering apparatus rather than as an intrinsic input into the intervention. Yet, it would seem unreasonable to assume that the effects that are observed could be replicated without observers deriving from major research organizations.

In the longer run, researchers should be expected to provide explicit detail on the nature of interventions, with special attention devoted to specific ingredients. Further, they should be required to separate both conceptually and empirically the ingredients that are developmental and experimental on the one hand from those that would be required for replication.

Many research studies that attempt to ascertain the effectiveness of interventions utilize both kinds of inputs. For example, the construction of program materials, development of program, and training of observers and researchers are not required for replicating an intervention. Yet, often portions of these activities are found to be enextricable in the presentation of research from those factors that would be required for replication. A clear distinction ought to be drawn between the two in writing research reports. Even more basic, all research reports should include a systematic presentation of the types and amounts of resources that were used in the intervention.

III. SPECIFIC INTERVENTIONS

The purpose of this section of the report is to review four specific interventions with respect to the elements of both their ingredients and cost structures. This review is based upon a review of studies that attempted to evaluate the intervention. In each case we will describe briefly the intervention and discuss its ingredients. We will devote special attention to the variants of the cost model with respect to each intervention.

1. Computer-Assisted Instruction

The plethora of computer-assisted instructional approaches makes generalization extremely difficult. They vary from specific instructional units that can be used to supplement regular instruction; to complete courses that are taken by computer; to continuous and year-long sequences providing drill and practice in support of the on-going instructional program in particular subjects. Each of these approaches has different objectives as well as providing a plethora of alternatives with regard to hardware, curriculum, and organization. As such, it is not possible to refer to CAI as an instructional intervention that has great specificity. In many respects, the different forms and uses of CAI represent different instructional interventions, as different as the diversity among different curricular interventions. Accordingly, the CAI model will not be a general one, but the particular one that was used as the basis for the ETS/LAUSD experiment.

This model has the virtues of having been tested for a number of subjects (mathematics, reading and language arts); most of the primary school grades; different intensities of treatment as well as durations of up to three years; and an excellent experimental and analytic design. Although the intervention addresses only the drill and practice capability of CAI, this is an important application and one that competes with other types of educational interventions in terms of attempting to improve basic skills. The resource cost model is approximated in Table One.

Table One

Ingredients of Resource Cost Model for CAI

Facilities -	Classroom containing terminals and CAI equipment as well as renovations necessary such as air-conditioning and security devices
Equipment -	Central processing unit, terminals, printer, and communications equipment if needed such as telephone lines, modems and multiplexers
Curriculum -	Rental of software required for instruction
Personnel -	Coordinators and aides as well as training
Miscellaneous -	Administrative, insurance, utilities, etc....

Table One shows the basic elements of the CAI model used for this analysis. Most of the ingredients are self-explanatory. The central processing unit and student terminals are situated in a special classroom that is air-conditioned and has special security arrangements to protect the equipment.

The equipment consists of the central processing unit (CPU) that stores the curriculum and student records and that provides the instruction and student terminals with keyboards and video screens. If the CPU is shared by more than one school, there are also costs for the communications equipment between schools. The curriculum includes the computer programs that are leased for use in the system. Personnel include the coordinator responsible for each CAI room and aides who answer student questions and assist the coordinator. Finally, there are a number of miscellaneous ingredients such as the administrative inputs, insurance and utilities.

Since the costs of this CAI approach have already been described and estimated in detail, it is best to refer to the more comprehensive study. In 1978, these costs were estimated at about $135 per student on an annual basis for each ten minute daily exposure to CAI. In later comparisons of costs, it is these estimates that will be used to compare with those of other interventions.

2. Reduction in Class Size

Probably the most universal and common strategy for improving student academic performance is that of reducing class size. Presumably the reduction of class size provides a number of benefits to students. First, students may feel that instruction is more personalized and less anonymous in smaller classes. Thus, students may feel more comfortable in the classroom environment, and teachers can tailor instruction more to the specific students in the class. A second and related possible benefit is that smaller classes do not require as much regimentation to keep order. To the degree that less time can be taken on the establishment and reinforcement of rules for maintaining order, there is more time for instruction. Finally, the smaller the class, the more time that teachers can devote to individualized instruction for each child during those parts of the teaching process that enable individual attention.

While smaller class sizes have this potential for improving instruction and academic achievement, it is not clear that they always realize this potential. Moreover, evaluations of their effects vary in rigor and the control of extraneous influences. Recently, Gene Glass and his associates have carried out a meta-analysis of the effects of class size on achievement. This analysis suggests that reductions in class size do have modest effects on achievement, with the size of the effect dependent on the magnitude of the reduction and the initial class size that is being reduced.

The ingredients model for reducing class size is relatively straightforward, encompassing two resources, teachers and facilities. Obviously, as a given student population is divided into more and more classroom units, more teachers are needed and more classrooms are needed. Thus, the resource cost model for any reduction in class size must estimate its impact on these two ingredients. By costing out the two ingredients, the cost of any reduction in class size can be estimated.

3. Tutoring

In a sense, tutoring represents the extreme reduction in class size by reducing the number of pupils for each instructor to a single person or just a few. However, more typically tutoring interventions do not fit well into the reduction of class size paradigm because they are devoted to remedial instruction or to subjects not covered in the normal curriculum such as advanced study for the gifted. Or, they can be used to simply reinforce what is covered in the regular course of instruction. Moreover, they are rarely taught by classroom teachers. Rather, the bulk of tutoring interventions in the public schools are based upon students of the same age tutoring others (peer tutoring) or older students tutoring younger ones (cross age tutoring). The usual arrangement is to choose a student with greater proficiency to assist one whose achievement has been lower in the peer tutoring approach. In some cases, parents or other adults have been used to totor youngsters.

The main advantage of the student tutoring model is that students represent a large potential teaching force. Thus, they can be an important resource in the instructional process. Second, studies have suggested that the tutors may benefit substantially in both self-esteem and in raising their own achievement levels by tutoring others, so both the tutor and the tutee may benefit from this process. Third, the approach has a high degree of flexibility in terms of subjects, tutors, pupils, required facilities, and so on. The approach can be highly formal with substantial training of tutors, structured exercises, tailored materials, and special facilities or highly informal with little or no training or structure and use of regular classroom materials as well as reliance on available space in hallways or other parts of the building. Finally, tutoring can be occasional for students who have difficulties with particular concepts or exercises, or it can be systematic for a given subject or for all subjects. Thus, even the amount of tutoring received by participating students can differ from a few hours to more than 100 hours a year.

The flexibility and richness of the tutoring model make it an attractive potential intervention for schools, but the variety of applications creates obstacles to the construction of a straightforward resource cost model to represent the approach. This can be readily discerned from Table Two which shows the ingredients for the tutoring model. Personnel include the supervisor or coordinator and tutors. But, the amount and qualities of personnel depend upon the specific tutoring approach. For example, the use of adults versus older students versus peers will have profound effects on the estimation of costs. From the perspective of students, the value of student time will depend on whether the activity takes place during school hours or after school. Presumably, the time of a student tutor should be evaluated only on the basis of the amount of learning that he or she foregoes during the school day. But, after school hours there is a value that is determined by employment possibilities or the value of other voluntary activities.

Table Two

Ingredients of Resource Cost Model for Tutoring

Personnel -	- Supervisor or coordinator - Tutors
Training -	- Time of trainer and tutor used for training process - Materials used for training and other ingredients
Facilities -	Tutoring space
Materials -	Specialized materials used for tutoring (beyond those used for regular instruction)

Other factors determining the personnel input include the length of tutoring sessions and whether the tutoring is supplementary or used for replacing regular instruction. The amount of supervision or coordination is also affected by these factors as well as the amount of training that must be given. Training differs substantially among different tutoring approaches, with obvious consequences for costs. The implications of facilities and materials on costs is also one subject to great variability. For example, among 23 tutoring studies, the range in tutoring time over a year varied from one hour to 180 hours with the median at only 2 hours a year.

Training time varied from none to 37 hours a year, with a median of less than one half hour. Similar variation is found in the use of facilities and materials.

Accordingly, cost models must be constructed that permit different configurations of ingredients to match the evaluations of effectiveness. A number of possibilities exist including providing estimates of costs for different variants of the tutoring model as well as specific cost estimates for those models that have been characterized by the most credible evaluations or other criteria such as implementability.

4. Teacher Retraining

A substantial part of the educational enterprise has been devoted to teacher retraining. The assumptions underlying this intervention are that teachers have been poorly prepared in the past, or that new evidence on teaching effectiveness has been discovered that should be conveyed to teachers to alter teaching practice. Without commenting on this rationale, it seems peculiar that teacher retraining should always take as given the inadequacies of existing teacher training without altering the basic training itself. That is, if teacher retraining represents an important "repair" to make up for the inadequacy of teacher selection or teacher education, then it would appear that the longer run solution is to improve teacher education and selection. However, many schools are faced with the dilemma of having large numbers of tenured teachers who could be far more effective than they presently are. The challenge is to find a retraining intervention that will improve their performance in raising achievement levels of their students.

While there is a long history of such efforts, the overall picture of teacher retraining is a glum one. In general, there has been little evidence that such interventions make much of a difference in teacher or student behavior. However, the last few years have witnessed a number of projects which have claimed success in improving the capacity of teachers to raise the achievement of pupils. In general, these approaches have in common the goal of getting teachers to divide the curriculum into highly structured units in which goals are made clear; general principles are advanced; specific examples are given followed by exercises with feedback to students; and finally an assessment of student performance is made. The teacher retraining intervention was disarmingly simple. Teachers were given a training manual that provided guidance for structuring lessons in mathematics. Training sessions were given to introduce teachers to the manual and its concepts and applications. Finally, teachers were observed to see if they were implementing the directions set out in the manual.

Table Three

Ingredients of Resource Cost Model for Teacher Retraining

Personnel -	- Trainer - Teachers during training - Observers
Materials -	Manual and other related materials
Facilities -	Space for training

Table Three sets out the rather simple list of ingredients for this retraining approach. Personnel include the trainer, the time of the teachers during the training period, and the classroom observers. Although the research studies stipulated that the observers were not a part of the intervention, but were only used to systematically gather data on teacher practices, it is difficult to believe that the observers did not have an effect on the teachers whom they were observing. Sponsors of the projects were some of the leading national figures in teaching effectiveness, and their students and colleagues served as observers. Accordingly, it is hard to argue that they were unobtrusive and not part of the "treatment." It is more reasonable to believe that teachers wanted to impress the observers with their preparation, teaching prowess, and adherence to the manuals. Accordingly, they are included as an input into this model.

Among the four projects, training time varied from three hours to 360 hours a year, with a mean of 97 hours. Observer time varied from 3 hours to 36 hours per year. The manual was relatively brief, only 20-30 pages, and our main concern is the replication or reproduction costs of this ingredient. Since there were only four projects, it seems sensible to estimate the costs of each - - that is, to view them as four separate models to compare with the four separate studies of effects.

Costing the Ingredients

At the present time attempts are being made to ascertain the costs of each of the ingredients. These will be estimated for each ingredient separately and aggregated for each model by major category of input as reflected in the earlier work of Levin and Woo (1981). Although the costs of specific ingredients may differ from locality to locality based upon local markets, it is important to base costs on some "average" figure. Of course, the cost estimates can be modified to take account of differences on a local level, but a meta-analysis should provide an overall or general picture. In the final section of this report we will consider some implications for a cost-effectiveness analysis.

IV - COMBINING COSTS AND EFFECTS INTO COST-EFFECTIVENESS MEASURES

The final step is that of combining the cost estimates generated by these models with the effectiveness estimates generated by Gene Glass into ratios of cost-effectiveness that can be compared among interventions. For example, the Levin-Woo estimates of costs for CAI for 1978 were about $135 per ten-minute session on an annual basis. According to the Final Report of the ETS/LAUSD project, such an intervention seemed to have the effect of increasing test scores in arithmetic computation for grades 1-6 by .36 standard deviations after one year of CAI, .56 standard deviations after two years of CAI, and .72 standard deviations after three years. (p. 164) According to Gene Glass, one standard deviation is about equivalent to one year of instruction at this level. Thus, we would like to compare a gain of .36 standard deviations for a one year intervention of CAI at a cost of $135 with the cost of obtaining similar gains through other interventions. Presumably some interventions will be found to provide larger effects per unit of cost than others. Moreover, if the differences are very large, we should consider seriously that the differences in cost-effectiveness are an important basis for selecting some interventions over others. However, a number of challenges and possibilities will be present that need discussion.

Joint Products or Multiple Outputs

One of the major challenges to the analysis will be that most of the evaluations are based on the examination of a single output. Yet, some interventions may produce changes in student achievement and other student outcomes along more than one dimension. An example is instructive. Suppose we compare two interventions on the basis of their costs and effectiveness in improving mathematics test scores, CAI and reduction of class size. The CAI will be tailored to produce improvements in mathematics proficiency, since the children will be exposed only to arithmetic drill and practice. In contrast, the reduction of class size will presumably affect all classroom activities, both the teaching of mathematics and other subjects. That is, it is probably fair to assume that the intervention of a drill and practice curriculum in mathematics for CAI should be evaluated primarily on the basis of its costs and effectiveness with respect to the mathematics outcome alone. One can search for other effects or joint outputs such as improvement in other subjects or in self-concept as a result of the CAI sessions in mathematics. But, if no other effects are found, it is probably correct to assign the entire cost of the CAI sessions in mathematics outcome alone.

But, in the case of a reduction in class size, clearly only a portion of the cost of the intervention should be assigned to the cost of mathematics instruction. Typically, only about one hour out of a five or six hour day in the elementary school curriculum is devoted to mathematics. Accordingly, only that portion of costs of reducing class size should be assessed as the cost of the class size intervention for improving mathematics achievement. At least five/sixths of the time over which a reduction in class size is operative is associated with other activities. The estimation of the cost-effectiveness ratio for improving mathematics achievement through the reduction of class size must take account only of the portion of the intervention attributable to the teaching of mathematics. Other work. such as that of Dean Jamison on cost-effectiveness of class size and other interventions, has tended to overstate the appropriate cost for reducing class size by assigning all of it to a narrow instructional domain that comprises a small part of the curriculum.

To summarize, each intervention will have to be evaluated to ascertain if all of the cost should be assigned to the specific domain in which effectiveness is being evaluated or only a portion of the cost. An alternative procedure is to specify a number of potential outcomes of the intervention including changes in achievement in a number of subject areas. These evaluations can then take account of multiple outcomes which can be aggregated into a single metric of effectiveness by applying utility weightings to the outcome. By using different utility weights to value the outcomes, the results can be subjected to sensitivity analyses and tests of robustness. Each utility index can be set against the total cost for producing that bundle of outcomes in the cost-effectiveness comparisons as illustrated in Levin 1976 and 1981.

Thus, the analysis of effectiveness for tutoring can include the improvements in achievement for both the tutors and their students, relative to what their achievement levels would be in the absence of the tutoring activity. Reduction in class size can be used to evaluate changes in achievement for the major subject domains, and so on. The basic problem with this approach is that not all of the evaluations choose to assess more than one area of outcome, and when multiple outcomes are assessed among interventions, they do not necessarily overlap among studies. For this reason, the apportioning of costs according to the use of resources for producing a single output is probably a more attainable procedure. Of course, even this approach assumes that joint costs of production are minimal, that is, that the costs of intervention can be separated according to the portion of them that are linked to a particular outcome. Whether this is realistic is problematic.

Cost-Effectiveness Within Interventions

A final possibility that is being explored with the data is that of cost-effectiveness analysis of variants of each model that permit comparison both among interventions and within them. For example, the large number of tutoring studies may enable some analysis of how both costs and effectiveness vary as one increases the amount of tutoring, amount of supervision, training time, and the extensiveness of materials. In the standard case familiar to economics we have two equations:

$$(1)\quad A = f\ (X_1, X_2, X_3, X_4)$$

$$(2)\quad B = p_1X_1 + p_2X_2 + p_3X_3 + p_4\,X_4$$

(1) corresponds to the standard production function concept in economics where the achievement of a student is a function of X_1 (hours of tutoring received), X_2 (amount of supervision), X_3 (training time for tutors), and X_4 (extensiveness of materials). It is assumed that A is an increasing function of each of the inputs, but that the law of diminishing marginal returns holds for each input so that at some point the additional achievement for a unit increase in each input (holding the others constant) begins to diminish. In the terminology of calculus, the first partial derivatives are assumed to be positive and the second are assumed to be negative.

(2) represents the budget equation. Given any level of budget for use on an intervention, the entire budget is allocated among the inputs according to the expenditure on each input which is determined by its price (p) and the amount of the input (X) that is utilized. The familiar form of the problem is to maximize (1) subject to the constraints of (2). The standard solution that derives from the lagrangian approach to constrained maximization is that each of the inputs will be utilized until that point where the additional contribution to A (achievement) for the last unit of X relative to the price of X will be equal for all inputs as in (3).

$$(3)\quad \frac{f'_{x_1}}{p_1} = \frac{f'_{x_2}}{p_2} = \frac{f'_{x_3}}{p_3} = \frac{f'_{x_4}}{p_4}$$

Using the work of Glass in reviewing the evaluations of tutoring, it might be possible to make some estimate of the parameters of (1); on the basis of the cost-analysis we can estimate the parameters of (2). These can then be combined to make estimates of variants of tutoring with respect to costs and effects of different combinations of the inputs.

Summary

The purpose of this report was to suggest how a meta-analysis of costs could be constructed and combined with a meta-analysis of effectiveness of educational interventions to provide a meta-analysis of cost-effectiveness comparisons. Clearly, this will be a first attempt at bringing together a wide variety of information from diverse studies in this form. As such, it should be considered tentative and provocative rather than definitive. Yet, if we are to benefit from an accumulation of knowledge that will inform policy decisions within a framework of limited resources, this is clearly the direction that we must go. A future report will provide the first estimates using the techniques set out in this paper.

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